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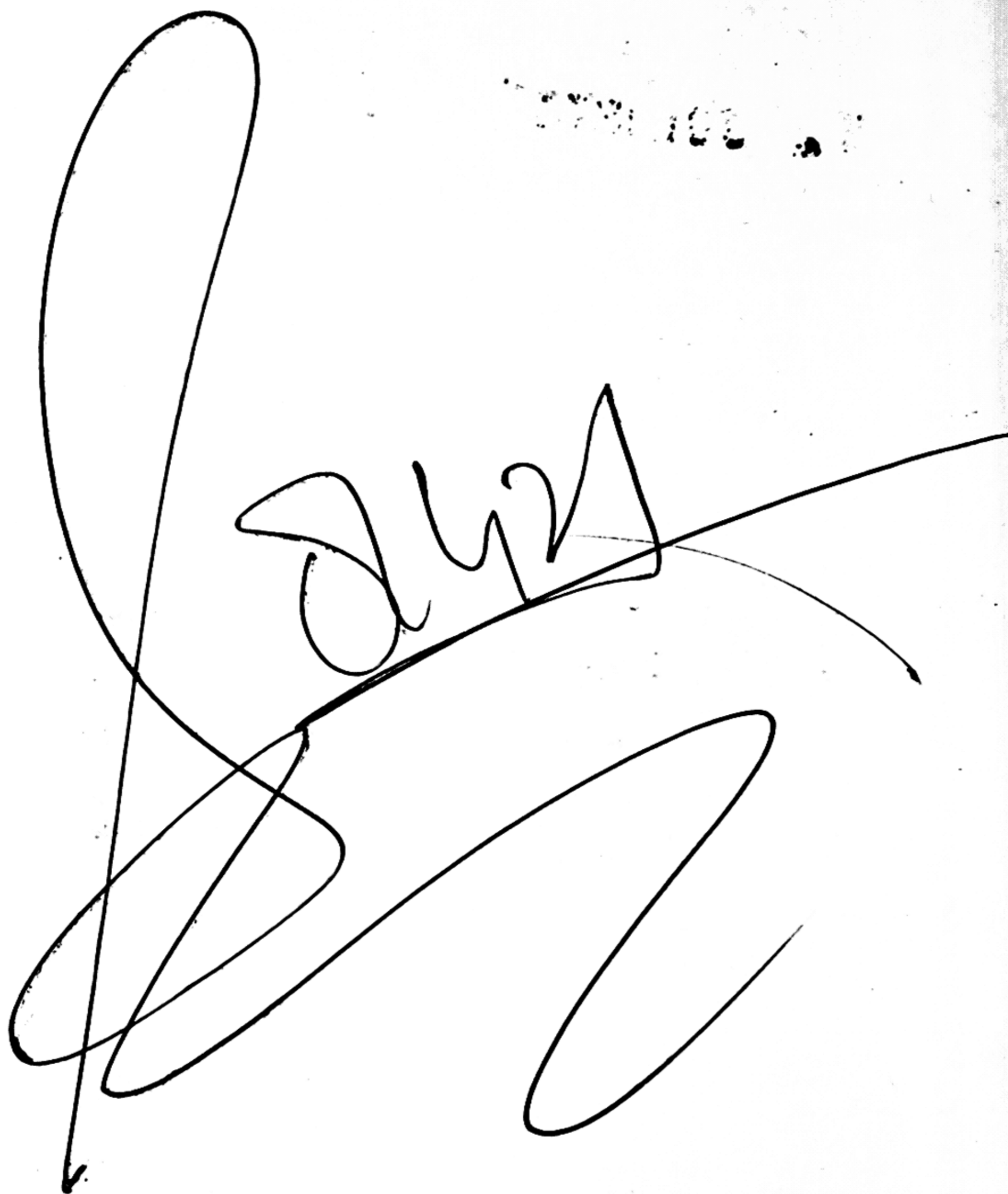
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THE
SCIENCE TEACHER'S
HANDBOOK

EVERYDAY SCIENCE TOPICS

Individual Work for Pupils

By T. A. TWEDDLE

BOOK I. Demy 8vo, 128 pages, with line diagrams in the text.

BOOK II. Demy 8vo, 160 pages, with line diagrams in the text.

BOOK III. Demy 8vo, 108 pages, with half-tone frontispiece and line diagrams in the text.

THE SCIENCE TEACHER'S HANDBOOK

*A COMPANION TO
Everyday Science Topics*

BY
T. A. TWEDDLE

HEADMASTER GLADSTONE STREET SECONDARY MODERN
BOYS' SCHOOL DARLINGTON
LECTURER ON SCIENCE TEACHING METHOD
LATE SPECIALIST TEACHER OF SCIENCE IN SECONDARY
MODERN SCHOOLS AND LECTURER IN PHYSICS AT THE
DARLINGTON TECHNICAL COLLEGE



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CONTENTS

CHAPTER	PAGE
I. SCHEMES OF WORK	9
II. APPLIANCES FOR EXAMINATION AND SUBJECTS FOR DISCUSSION	14
III. DEMONSTRATION EXPERIMENTS AND MODELS AND SOURCES OF INFORMATION	24
IV. ELECTRICITY IN THE SCIENCE ROOM. AQUARIA. A SCIENCE TIME CHART	194
V. OPTICAL AIDS IN THE SCIENCE ROOM	204
VI. SCHOOL-MADE OPTICAL AIDS	217
VII. THE SCIENCE ROOM LIBRARY	236
INDEX	245

CHAPTER I

SCHEMES OF WORK

THE three books of *Everyday Science Topics* and this teacher's book are based on a scheme of work which has been in use in post-primary schools for the last ten years. All the models have been made, the practical work carried out, and the individual work described in the pupils' books has been performed many times by pupils of twelve to sixteen years of age. The topics are based on the pupils' interests, needs, and possible future occupations and are intimately connected with their everyday experiences.

In the Secondary Modern Schools we are not to attempt to train scientists. The pupils should be led to realize the important part played by science in the modern world, and they should acquire some knowledge which will enable them to deal with its applications. Our pupils, unlike those in the Grammar Schools, do not need instruction in science for examination purposes. In the words of the Board's *Suggestions*: "We are free from cramping traditions and the necessity of preparing for examinations, and this offers us an opportunity to develop science-teaching on fresh lines. To take what is good from old ideas and experiment freely with new ones." By the topic method of teaching we make use of things and phenomena met with in the everyday life of the pupils. Interest is easily aroused, knowledge of practical importance is imparted, and the relative importance of the scientific principles involved is soon realized. It is the method used by a practical man when teaching out of school. He attacks the topic directly, and the principles come in only when needed. In some Secondary Modern Schools far too much time has been spent on the verification of principles discovered by scientists long ago. Pupils should start at the point reached by scientists after generations of thought and labour. By the topic method of teaching fundamental principles keep cropping up over and over again, and are explained and tested only in sufficient detail to give a clear understanding of the matter in hand. Excellent revision is thus provided, and the relative importance of the principles is understood.

During the study of any one topic a considerable amount of coherence is assured, but some steps must be taken to prevent the scheme as a whole from being an inconsequent succession of unrelated bits of study. All topics may be grouped under the one major

heading "Science and our Daily Lives," and minor topics may be grouped under such headings as "Science in the Home," "Science in the World Outside," "Science and Health," "The Science of Common Things," etc.

Usually the first-, second-, and third-year topics will be under discussion at any given time. The laboratory should be cleared of everything which bears no relation to these subjects. There should be pictures and charts on the walls, models and appliances on the benches and shelves, and picture post-cards, newspaper-cuttings, catalogues, films, film-strips, slides, and books available for reference purposes. For the display of pictures beaver board in wooden frames may be fixed to the walls. Ample room for the storage of models, plans, charts, etc., which are not being used should be available near the science room. It is a good plan for the pupils to help to collect and store such material in drawers or boxes, labelling these with the names of the topics. Much useful equipment can often be obtained from local sale-rooms, garages, and the pupils' homes.

Every appliance mentioned should, wherever possible, be shown and examined in the science room. Local tradesmen and manufacturers all over the country are generally willing to assist in this way as far as conditions allow. The catalogue of the British Industries Fair will be found most helpful. It contains an index of exhibits, including most of the things mentioned in these books, and an alphabetical list of exhibitors with their addresses. Particulars of manufacturers of appliances not mentioned in this catalogue can always be obtained from the various journals and magazines to be found in the local library. Where appliances to be examined cannot be brought into the science room, then the pupils should be taken to see them, as, for example, to the local gas and electricity showrooms.

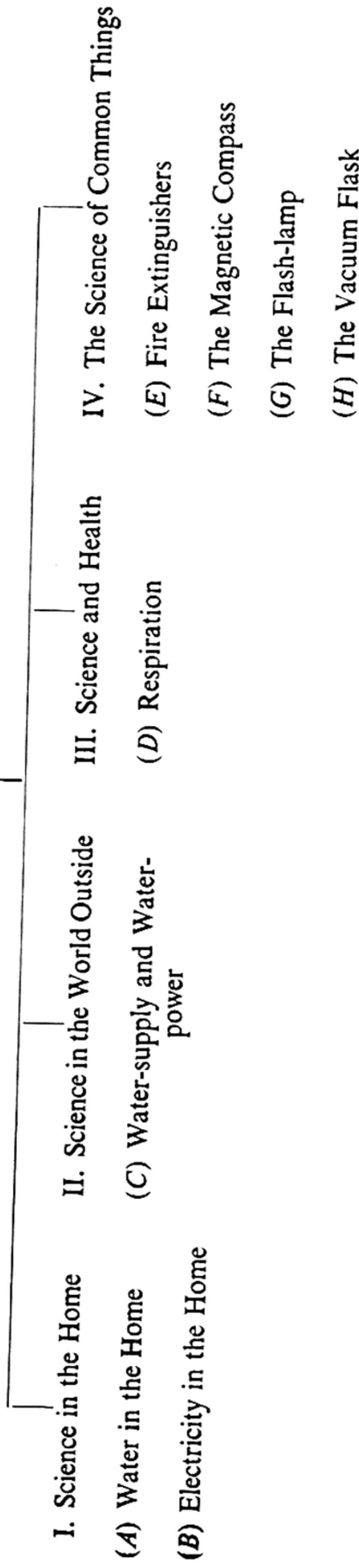
For building up a scheme of work a suggested arrangement of material is:

SYLLABUS OF WORK	SOURCES OF INFORMATION	PUPILS' MODELS AND EXPERIMENTS	TEACHERS' DEMONSTRATIONS

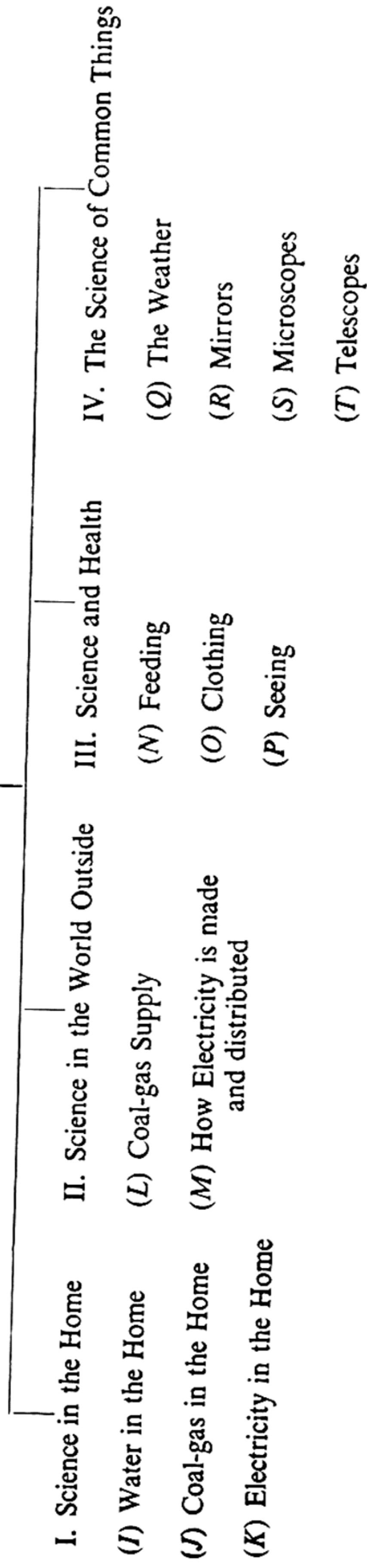
DIAGRAMMATIC REPRESENTATION OF A SUGGESTED ARRANGEMENT OF TOPICS

Science and our Daily Lives

Part I



Part II



In the first column are noted details of topics, subjects to be discussed, and appliances to be examined. It is a good plan to note here after each group of lessons the subjects that have cropped up spontaneously for discussion, even though these may be a little outside the scope of the topic. In the second column particulars of information in books, manufacturers' catalogues and samples, visits, pictures, slides, films, etc., are noted, so that this material can be made readily available when lessons are being prepared. In the third column details of simple models and experiments for the pupils are noted. Here, again, the material for the pupils' experiments should be collected and stored in labelled boxes or drawers. In the last column details of teachers' demonstration models and experiments are kept. All this information is noted from day to day as it is discovered in searching through books and magazines or as material is collected.

It is a good plan to note alphabetically during the development of a scheme of work the small pieces of equipment and material which must be purchased. This will be found helpful when orders for materials have to be completed in later years.

Much of the apparatus required can be made from scrap. Very little of the more usual type of laboratory equipment is necessary. Money which used to be spent on sensitive balances, burettes, etc., is by this means made available for building up a good reference library of the many excellent science books available, and for buying a good 16-mm.-film projector, which should be among the first pieces of equipment to be purchased. Such a projector is an indispensable teaching aid, and, while care must be taken that optical aids do not dominate our teaching, they are excellent for the introduction or revision of a topic and for emphasizing certain points during lessons.

Particularly suitable for this purpose are some of the Dance-Kaufmann short-loop films (Dance-Kaufmann Technical Films, 18 Upper Stanhope Street, Liverpool, 18). It is possible to make quite an efficient optical lantern, episcopes, micro-projector, and film-slide projector. It is advisable to have separate instruments for episcopic and diasopic projection. With regard to the technique of the use of optical aids in the science room the Board of Education Pamphlet No. 115, *Optical Aids*, gives much useful information, and more is given later in this book. The episcopes described in the chapter on School-made Optical Aids should be one of the first things to be made, so that the numerous illustrations referred to can be used during lessons on the various topics. The lantern, episcopes, cine-projector, and micro-projector should be permanently mounted ready for use in a separate science lecture room if possible.

It may appear that certain subjects and appliances mentioned are out of place under certain topics. They have been included there because they came up for discussion quite naturally during the building up of the scheme of work.

All the models are excellent teaching-aids, and can be made quite easily by amateurs. There are many books which describe the kinds of tools and materials required to construct the models and how to mark out, cut, file, drill, and bend sheet metal, metal rod, strip, and tubing, how to solder, etc. A good book for this purpose is *The Laboratory Workshop*, by Duckworth and Harries.

In Secondary Modern Schools, I think, the best way to introduce the study of biology is by means of the topics under the heading "Science and Health"—e.g., Respiration, Feeding, Clothing, Seeing, Hearing, Disease, etc.

If there is any difficulty in obtaining biological specimens locally, they can usually be obtained from L. Haig, Beam Brook, Newdigate, Surrey, or T. Gerrard and Co., Ltd, 48 Pentonville Road, London, N.1.

It will be seen that actual work in science when following this type of scheme may consist of any of the following activities as pupils or teachers may desire: demonstrations by the teacher, discussions, making of models, examination of catalogues, pictures, lantern-slides, films, film-strips, appliances or models, reading of sections in books on the topics under discussion, or the carrying out of individual practical work as described in the pupils' books.

This Teacher's Book, in the words of the Board of Education Pamphlet No. 89, *Science in Senior Schools*, aims at "covering a common core of the matter suitable for large groups of schools." Even then, however, such a book cannot cover the whole field. Fresh, stimulating teaching can be based only on the teacher's own living interests. Even the very best book in the hands of a teacher who understands his task is only a source from which some ideas are selected, not a guide to the topics to be studied, the order of their presentation, or the method by which they are to be approached.

CHAPTER II

APPLIANCES FOR EXAMINATION AND SUBJECTS FOR DISCUSSION

THIS chapter gives details of the appliances for examination and subjects for discussion under the various topic headings as set out in the scheme of topics. For quick-reference purposes each topic is labelled *A*, *B*, *C*, etc.

This is the type of information which would be included under the heading 'Syllabus of Work' in the first column of the scheme of work:

PART I

I. SCIENCE IN THE HOME

(A) Water in the Home

Household taps, anti-splash fittings, surface tension, dripping taps—calculation of waste.

Ball-taps: flotation.

Pressure of water-supply. Plug-taps for low pressures.

Comparison of the pressure of the water-supply with the pressure of the gas-supply. Divers and diving.

Hand-flushing tanks; automatic flushing tanks; the siphon; the automatic siphon; water-traps; water-closet basin; water-levels.

(B) Electricity in the Home

The electric bell and electric buzzer—working and construction.

Defects in inferior bells.

Bell-pushes: various types.

Bell circuits. What is meant by a circuit.

Conductors and insulators.

Bell-indicators.

Electro-magnets: why some are stronger than others.

Other uses of electro-magnets: electro-magnetic cranes; brakes; separators; lamp-holders; medical electro-magnets.

The solenoid and its uses: motor-car direction-indicator and electric hooter.

The Leclanché cell. Dry cells and batteries.

The simple cell. Polarization.

Detecting an electric current.

Galvani, Volta, Ampère.

II. SCIENCE IN THE WORLD OUTSIDE

(C) Water-supply and Water-power

Situation of waterworks and reservoirs.

Pumps: Archimedian screw, suction and force pumps.

Wells. Centrifugal pumps.

Settling-tanks and filters. Chlorination of water.

Properties of chlorine. Water-meters, water-towers, head of water.

Hydraulic rams and lifts. Floating intakes.

Fountains.

Water-turbines and water-wheels.

Head-pressure gauge.

III. SCIENCE AND HEALTH

(D) Respiration

What is air? Its composition and properties.

The work of Lavoisier and Priestley.

Preparation and properties of oxygen, nitrogen, and carbon dioxide.

Air essential for all living things—plants and animals.

Air essential for combustion and rusting.

Which part of the air is used during breathing, burning, and rusting?

Production of carbon dioxide, water-vapour, and heat during respiration and burning.

Candles and matches.

How plants and animals breathe.

The balance of life in air and water.

The aeration of aquaria.

The respiratory system in man. The process of respiration.

The mechanism of inspiration and expiration. Comparison with action of a bicycle-pump.

How the oxygen of the air is taken up and carbon dioxide given out by the lungs.

Chemical processes in the body similar to combustion, producing water, carbon dioxide, and heat.

Respiration at great altitudes.

Flügge's observations. Humidity and temperature. Water-vapour in expired air.

Impurities in the air. How dust and soot cut off sunlight.

Respirators. The Smoke Abatement Society.

Fresh air and disease.

Ventilation: natural and artificial.

Diffusion in gases. Convection.

The nature of sunlight. The spectrum.

Ultra-violet and infra-red rays.

Sunlight for the cure of rickets and tuberculosis.

Sunbathing. The Sunlight League and its work.
Ultra-violet glass.
Artificial-sunlight lamps.

IV. THE SCIENCE OF COMMON THINGS

(E) Fire Extinguishers

The nature of fire. Air necessary for combustion.
Which part of the air is used. Oxygen and its properties.
Use of water as a fire extinguisher.
The fire-engine pump.
Various types of fire extinguishers: the break-bottle type and the turn-over type.
Carbon dioxide and its properties. Carbon-dioxide-gas extinguishers.
Fires of inflammable oils and spirits. The foam type of extinguisher.
Carbon-tetrachloride-pump type of fire extinguisher.
Properties of carbon tetrachloride. Danger of phosgene gas generated when using carbon tetrachloride in a confined space.
Fire prevention. Fire alarm.
How to deal with a person on fire.
Burns and their treatment.

(F) The Magnetic Compass

The magnetic compass: its use and construction.
The points of the compass.
Lodestone. William Gilbert.
Properties of magnets: magnetic induction, magnetic substances.
Magnetism penetrates paper, wood, glass, etc.
Temporary and permanent magnets. Types of magnets.
How to make magnets. The difference between a magnetized and an unmagnetized piece of steel.
Core of magnets. Magnet screening.
Lines of force. Fields of force.
The earth as a magnet. The ship's compass. The dip-needle.
Discovery of the earth's magnetic poles by Ross and Shackleton.

(G) The Flash-lamp

Various types of flash-lamps and cycle lamps.
Simple electric-lamp circuits.
The batteries, switches, and circuits in various types of lamps.
The bulb: how it is constructed.
The reflector: reflection from plane and curved mirrors.
The lens: the action of lenses—refraction.

(H) The Vacuum Flask

Construction of a vacuum flask.
The purpose of the cork cushion and rubber collar.

Dewar and his work.

Conduction of heat. Glass, cork, rubber, and water are poor conductors.

Why glass cracks when boiling water is added.

Radiation of heat. Reflection of radiant heat.

The safety-lamp—Davy.

Action of the vacuum in the flask.

Exhausting pumps.

PART II

I. SCIENCE IN THE HOME

(I) Water in the Home

Water and ice. The expansion of water on solidification.

Why ice floats. Icebergs.

The freezing of water-pipes. How to avoid the bursting of pipes.

Remedies to be applied when pipes burst.

Ice-boxes.

Why ice forms on the surface of water.

The temperature of water when a given weight occupies the smallest volume.

The disintegration of rocks and soils by frost.

The change from the liquid to the solid state in other substances, and the heat and volume changes which take place.

The effect of pressure on the solidifying temperatures of substances.

Composition of water. Analysis and synthesis of water.

Preparation and properties of hydrogen.

Balloons and airships.

Preparation and properties of oxygen.

(J) Coal-gas in the Home

Gas-taps: the plug tap; by-pass taps; regulation of gas consumption with the tap.

The Bunsen burner. The gas-ring. Early examples of burners. Lighting the gas.

The flint and electric gas-lighters. William Murdock. Robert Wilhelm Bunsen.

The gas-fire: parts of a gas-fire; the burner; lighting back; the radiants; convection in air; ventilation, radiation; radiation hob for use with gas-fires.

The gas-radiator.

The gas-cooker. Economies in the use of gas when cooking. Boiling-points of water and solutions. Why flues are necessary. How to show that flues are efficient.

Gas water-heaters: gas-geysers. Safety devices in geysers. Convection in liquids. Conduction in solids.

Thermostats: expansion and contraction of solids. The uses of invar steel.

Gas-refrigerators: cold produced by evaporation of liquids.

Gas-lighting: flat-flame burners; incandescent-mantle burner; globes and shades; switches for gas-lighting; time switches.

The gas-meter: how to read the meter; the British Thermal Unit; why coal-gas sometimes explodes.

Gas clinical lamp. Soldering iron and launderer's iron. Cost of using gas appliances.

(K) Electricity in the Home

DOMESTIC APPLIANCES WORKED BY ELECTRIC MOTORS

The electric vacuum cleaner, the electric washer, floor-polisher, fan, and hair-drier.

The electric motor—various types.

Construction and working of electric motors.

Interaction of currents and magnets.

Simple electric motors: Barlow's wheel, Sturgeon's disc, Faraday's motor.

Action of parallel currents. Roget's spiral.

ELECTRIC LIGHTING

Construction of electric lamps. Heating effect of electric current.

Why the filament is in an exhausted bulb.

The wattage consumption of lamps and their illuminating powers.

How to calculate the cost of using lamps.

The efficiency of lamps. The difference between cheap and expensive lamps. Gas-filled lamps.

Coiled-coil filaments, tubular lamps, decoration lamps, opal, clear, and pearl lamps. The mercury-vapour lamp.

The effects of using lamps of the wrong voltage.

Shading electric lamps.

Gloom: effects of insufficient lighting—causing eyestrain through inadequacy of light for sewing, reading, etc.

Glare—direct and reflected glare. Intensity of illumination. Illumination meters. Importance of keeping fittings clean. Light absorbed by dirt.

Illuminating powers—comparison of illuminating powers.

Absorption and reflection of light—effect of the colours on walls of rooms. How to change the wall colours in a room by coloured lighting. Effect of the colour of incident light on coloured materials. Matching colours by artificial light and daylight. How increased illumination helps acuity of vision. Importance of this in workshops and factories and in the home. Risks of accidents due to insufficient lighting. How the direction and position of lighting increases comfort and safety of operations and speed of output.

II. SCIENCE IN THE WORLD OUTSIDE

(L) Coal-gas Supply

Preparation and properties of coal-gas.

When gas and air form an explosive mixture.

Danger of playing with gas. Gas lighter than air.

Used for filling balloons.

Situation of gas-works. Compare with situation of water-works.

Elasticity of coal-gas. Rough analysis of the gas.

Kind of coal used for making gas.

The formation of coal—a treasure that should not be wasted.

Carbonization of the coal. Gas-making retorts.

Coke and its uses.

Retort carbon—uses for making carbon rods for electric-arc lamps, etc.

From retort to gas-holder—cooling the gas, collecting the tar, washing out ammonia. Use of ammoniacal liquors. The purification of the gas.

The gas-holder (so often erroneously called the gasometer).

No waste in a gas-works. The by-products of gas manufacture. Uses of the by-products.

The gas-pressure—why this varies during the day. Measurement of gas-pressure. Thermal value of gas. How to calculate this.

The history of gas-supply. William Murdock's experiments.

Street-lighting by gas. Time-switches.

(M) How Electricity is made and distributed

Where the town's electricity comes from. Situation of the electricity works.

The dynamo—construction of the dynamo. Magnetically and electromagnetically induced electric currents. The magnetic field of a bar magnet, a coil of wire, and a coil of wire with a soft-iron core.

How an electric current is produced in a circuit when the magnetic conditions near it are changing. Direct-current and alternating-current dynamos.

Properties of direct and alternating current.

How dynamos are driven—steam engines, steam turbines, and water-power.

Wind-driven dynamos.

How electricity is transmitted from the dynamos to various parts of the town.

Why electric-supply companies have changed to alternating current.

Electric power and its distribution. How power is lost as heat in a circuit. High cost of copper cable. High-pressure distribution to save cost of cable. Difficulty of building high-pressure D.C. generators owing to breakdown of insulation in commutator. High-pressure alternators—why practicable. High pressure unsuitable for a customer's premises. The transformer—how high-pressure A.C. can be stepped up or down with

transformers. These transformers require no attention. Raising and lowering a D.C. voltage a more difficult matter.

Types of cable used. Situation of transformers in the town. The Grid.

The nature of the town's electricity supply—voltage, frequency, etc. The rectifier and its use. Michael Faraday.

III. SCIENCE AND HEALTH

(N) *Feeding*

Feeding in plants and animals.

How plants obtain their food.

The effect on plants of insufficient and wrong feeding.

Digestion in man—types of foods.

Composition of typical foods.

(O) *Clothing*

Evolution of clothes. Man by nature unclothed. Primitive man unclothed to-day. First object of dress—adornment. Painting and tattooing before clothes were worn.

Why clothes are necessary: (i) to prevent excessive loss of heat; (ii) to protect the body from excessive heat and sunlight; (iii) to protect the body from wind and rain; (iv) to protect the body from injury; (v) to adorn the body.

How heat is generated in the body. The temperature of the body. Use of the clinical thermometer. How heat is lost through the skin—conduction, convection, radiation, and evaporation.

Materials used for clothing: (i) from the vegetable kingdom—cotton, linen, rubber, artificial silk; (ii) from the animal kingdom—wool, fur, silk, leather.

Properties of textiles: (i) structure of fibres; (ii) elasticity; (iii) capacity for absorbing moisture; (iv) how they burn; (v) strength.

VARIOUS TYPES OF FABRICS MADE FROM TEXTILES

Properties of these types of fabrics: (i) price; (ii) weight; (iii) hardness; (iv) do they shrink when washed?; (v) do they absorb moisture?; (vi) are they good or bad conductors of heat?; (vii) do they absorb odours?; (viii) strength; (ix) capacity to admit light and air; (x) how do they burn?

The colour of outer garments. White and light-coloured clothing absorbs less heat and has much less affinity for organic matter and germs. The dangers of flannelette. The dangers of wearing damp clothing.

WHY THE SKIN SHOULD BE EXPOSED TO AIR AND LIGHT

Cellular clothing. Excessive clothing bad. Men's dress particularly bad because of: (i) its excessive weight; (ii) its tightness; (iii) it is often unhygienic.

Irrationality of modern dress conventions for men. How the changes in

women's dress have improved their health. Why certain types of water-proof clothing are bad.

(P) *Seeing*

The eye compared with a camera.

Parts of a camera. Functions of the various parts.

Structure of the eye.

Defects of vision. Spectacles.

How the eye is protected from injury.

Conditions conducive to defects of vision.

The pin-hole camera.

Taking and making photographs.

IV. THE SCIENCE OF COMMON THINGS

(Q) *The Weather*

THE BAROMETER AND AIR PRESSURE

The simple mercury barometer.

The weight of the air. The work of Torricelli and Von Guericke.

Effects of air pressure: the fountain-pen filler; self-filling fountain-pen; syringes; water-pumps; pipettes; the siphon; etc.

The Fortin barometer.

The aneroid barometer and barograph. How the barometer is used as a weather-glass. How air pressure varies with altitude. Use of an aneroid barometer as an altimeter.

The Everest Expeditions. Breathing at great altitudes. Pressure on the human body. Effect on health.

The value of simultaneous readings of the barometer at a number of localities spread over Great Britain and the Continent.

Isobars. Winds. The Beaufort Scale. The anemometer.

Effect of variation of pressure on boiling-points of liquids. Uses of this in cooking and in industry.

Methods of fixing lids in canning and bottling works.

The air pump.

Flotation in air: airships and balloons.

RAIN, THE RAINBOW, LIGHTNING, THE SUN, AND METEOROLOGICAL OBSERVATIONS

Rain. The rain-gauge: construction and use. Methods of recording rainfall. Moisture in the atmosphere. How it gets there. Evaporation. Conditions under which evaporation takes place. Latent heat. Cold produced by evaporation. Why moisture from the sea is not salty.

Distillation. Clouds: how they are formed. Classification of clouds. Formation of rain, fog, mist, dew, hoar-frost, snow, and hail. Effect of dust and soot particles in the formation of fog. Hygrometers. Damp-detectors. Use of seaweed, etc. Measuring the moisture in the air.

Substances which take moisture from the air. Wet- and dry-bulb thermometers.

The rainbow: how it is formed. The composition of white light. The colours of the sky.

Lightning and thunderstorms: Benjamin Franklin and his work. The nature of lightning.

The speed of sound and light: calculating the distance away of a thunderstorm. Lightning conductors—how they act.

How the sun warms the earth: sunshine recorders. The thermometer. Temperature and heat. The unreliability of our temperature sense. Thermometric scales. Fixed points of thermometers. Maximum and minimum thermometers. Thermometer shelters. The Stevenson screen. The thermograph. The Rototherm. Variation of temperature with altitude. The work of Jean Rey, Leopold de' Medici, Galileo, Fahrenheit, Celsius, and Réaumur.

Meteorological observations: methods of recording. A school meteorological station. International symbols for recording weather phenomena. Weather forecasts.

(R) Mirrors

Various types of plane mirrors: polished metal; glass backed by thin layer of deposited silver; glass coated in front with a thin layer of silver very highly polished.

Reflection of light by plane mirrors. The position of the image. Lateral inversion.

Everyday appliances in which plane mirrors are used: the periscope; office windows in dark streets; the heliograph; mirrors in shop-windows. Pepper's Ghost. Pulsometer. Graphoscope. Daylight signs. Looking through a block of stone. Use of mirror for measurement of small angular deflections.

The action of other smooth surfaces as reflectors—smooth surfaces of liquids, glazed paper, glass. The non-reflecting shop-windows.

Glass prisms as reflectors in lampshades and telescopes. The kaleidoscope. Reflection from mirrors at an angle. Shaving-mirrors, motor-car drivers' mirrors, motor-car headlight mirrors. Crazy mirrors.

Reflection from curved and spherical mirrors. Positions of objects and images with spherical mirrors. Spherical aberration. Formation of caustic curve by reflection.

(S) Microscopes

Simple magnifying glasses. Reading-lenses and pocket magnifiers. Images formed by convex lenses—nature of the images. Leeuwenhoek and his work. Other pioneers with the microscope. Spherical and chromatic aberration in lenses. The compound microscope—its uses and construction. How to use a microscope. Projection with a microscope. The micro-projector. How to obtain on a screen or the page of a book an enlarged image of a microscopic object. Photography with a microscope. The photomicrograph. How to make photographs of microscopic objects.

(T) Telescopes

Derivation of the word 'telescope' (Greek, *tele*, far; *skopein*, to see).
Construction and uses of the various forms of telescopes.

ASTRONOMICAL TELESCOPES

Refracting type—magnification produced.

Why telescopes are made large. Nature of objective and eyepiece. Chromatic and spherical aberration. Methods of eliminating these. Limitations to increases in aperture possible in refracting telescopes.

Reflecting type—image formed by concave mirror. Advantages of this type.

Different methods of observing images formed in reflecting telescopes devised by Cassegrain, Newton, Herschel, and Gregory.

Some of the world's greatest reflecting telescopes. Why the mirrors are made so large. How spherical aberration is eliminated by using paraboloidal mirrors. How the mirrors are made. No obstacle appears to limit size of reflectors.

SIMPLE INTRODUCTION TO ASTRONOMY

The meaning of a year for each planet. Day and night. The moon and other satellites.

Uses of astronomy: time, tides, shape and size of the earth, navigation, direction by Pole Star.

Some great astronomers: Copernicus, Tycho Brahe, Galileo, Kepler, Huygens, Flamsteed, Cassini, Newton, Halley, Bradley, Roemer.

Terrestrial telescopes—use of extra lens to re-invert image. Prism binoculars.

Galilean telescope—opera glass. Shorter than astronomical telescope. Of equal magnifying power. Image erect.

The development of the telescope. Exact date of discovery uncertain.

Lippershey, Galileo, Kepler, Huygens, Gregory, Newton, Cassegrain, Hall, Dolland, Herschel.

DEMONSTRATION EXPERIMENTS AND MODELS AND SOURCES OF INFORMATION

IN this chapter are given details of sources of information, books, films, lantern-slides, film-strips, pictures, demonstration experiments, and models which have been found helpful. This information cannot be complete and exhaustive, on account of the limited space, and much that I should like to include will have to be omitted. No attempt is made to give full details of the methods of dealing with the topics, as it is felt that the method of attack must be left to each individual teacher to work out for himself.

(A) Water in the Home

When work is commenced on any topic an effort should be made to collect together in the science room samples of all the appliances to be mentioned. It will take time and patience, but manu-

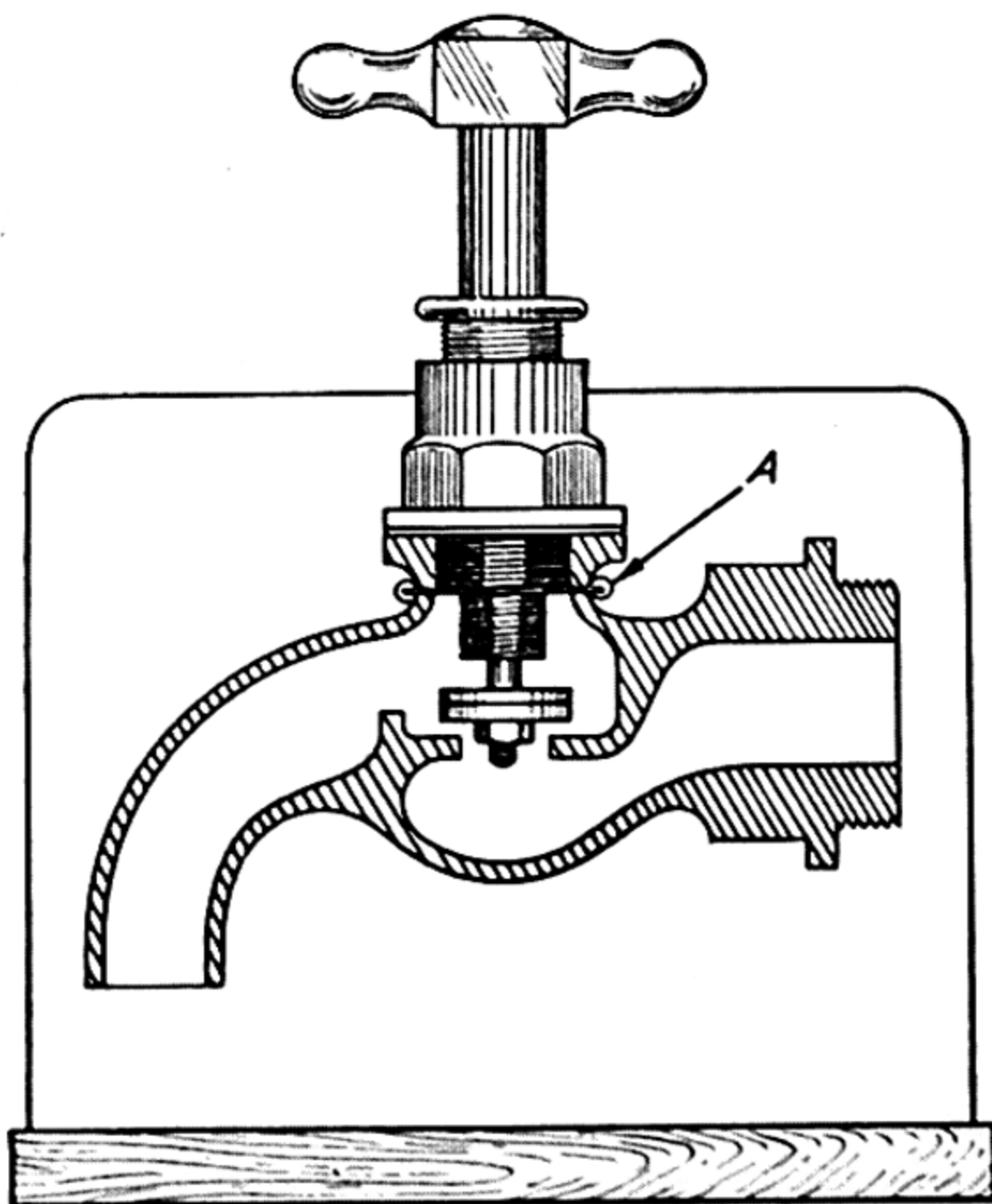


FIG. 1. WATER-TAP SAWN IN HALF

facturers and local plumbers and tradesmen will generally be quite ready to lend or give appliances and catalogues containing useful information and illustrations. The collection of taps should include bib-cocks, stop-cocks, plug taps, and ball taps, which can be easily dismantled so that their interior construction can be examined and pupils may practise fitting new packing in the collars and new washers on the jumpers. It is very helpful if a screwed water-tight connexion with a laboratory tap to the various appliances can be made.

Large coloured drawings showing the various taps, tanks, etc., in section are helpful and should be made by the teacher.

Demonstrating the Action of the Washer in a Water-tap

Remove the whole of the upper part of the tap, including the jumper and washer, and place the lower part in a vice. Cut it in half with a hack-saw. One half can be thrown away. The other

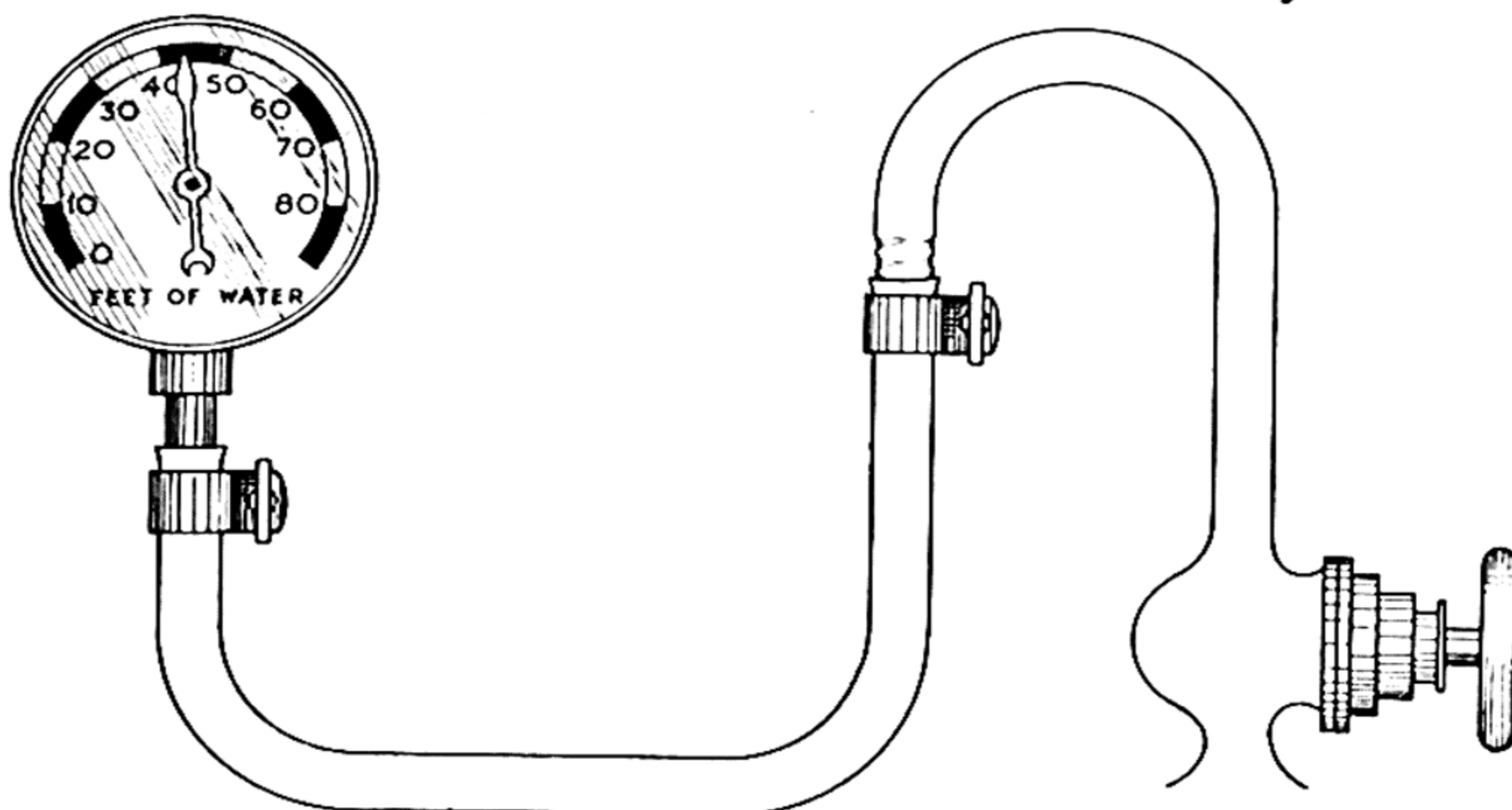


FIG. 2. APPARATUS FOR MEASURING HEAD OF WATER

half can be fixed to the upper part of the tap with a wire (A) and the whole mounted on a wooden stand, so that when the handle is turned it can be seen how the spindle holding the washer moves up and down. The same can be done with a bath-tap and a stop-cock.

Measuring the Head of Water or the Height of the Water in the Reservoir above a Water-tap

This can be done by connecting a water altitude meter, obtainable from the manufacturers, to a water-tap by means of pressure tubing firmly fixed with clips to the gauge and the tap.

The pressure of the water can also be measured by balancing it against a column of mercury in a strong glass U-tube, with the arm A, about 5 feet long, connected to the water-tap in the same way as the altitude gauge.

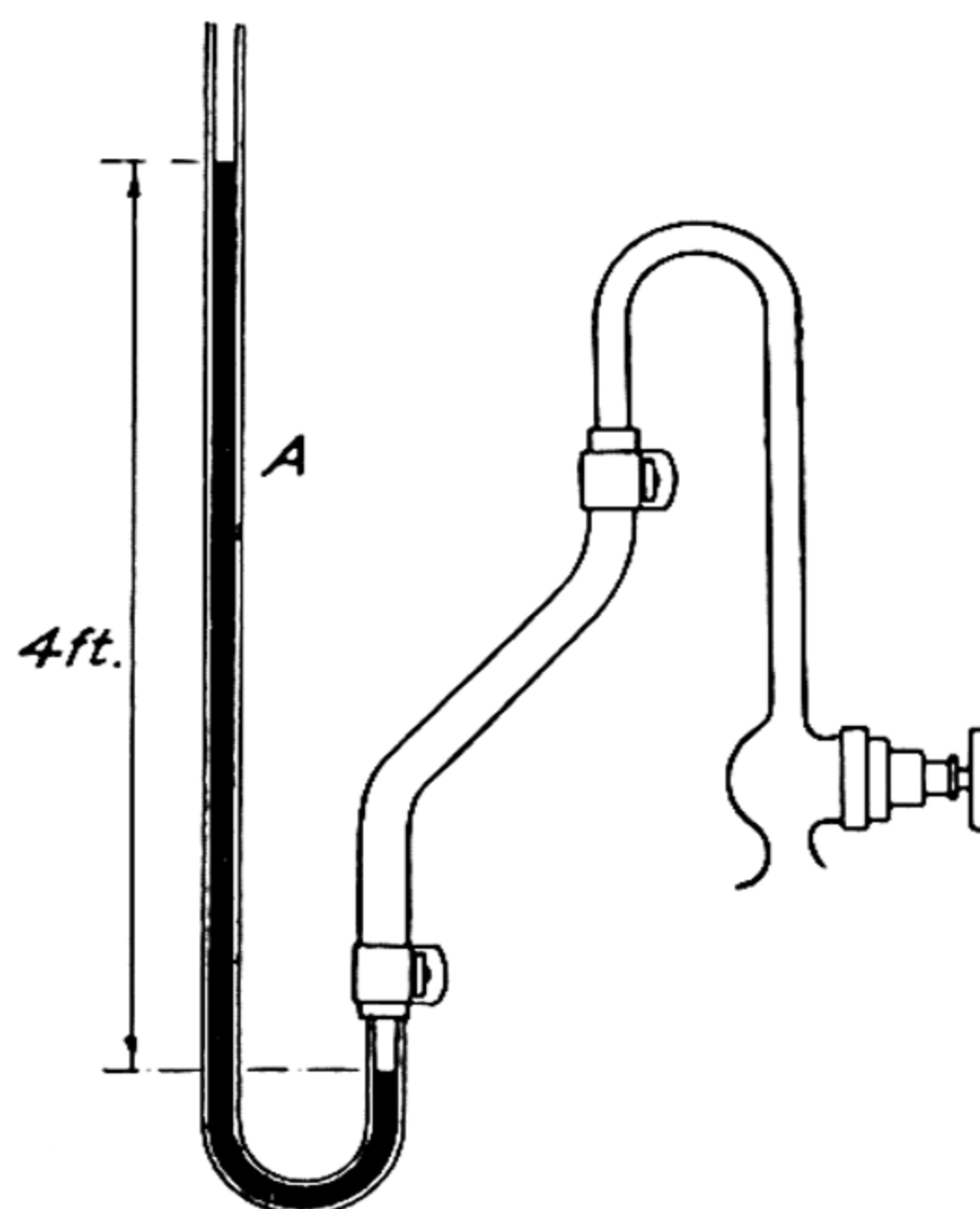


FIG. 3. APPARATUS FOR MEASURING WATER PRESSURE

If the water supports a column of mercury 4 feet high it would support a column of water $13.6 \times 4 \text{ feet} = 54.4 \text{ feet}$ high, because mercury is 13.6 times as heavy as water. It is on account of this great pressure that a screw-down tap is required to hold back the water.

Demonstrating the Functions of a Plug Tap

To demonstrate the functions of a plug tap and at the same time show the low pressure of the gas in the laboratory as compared with

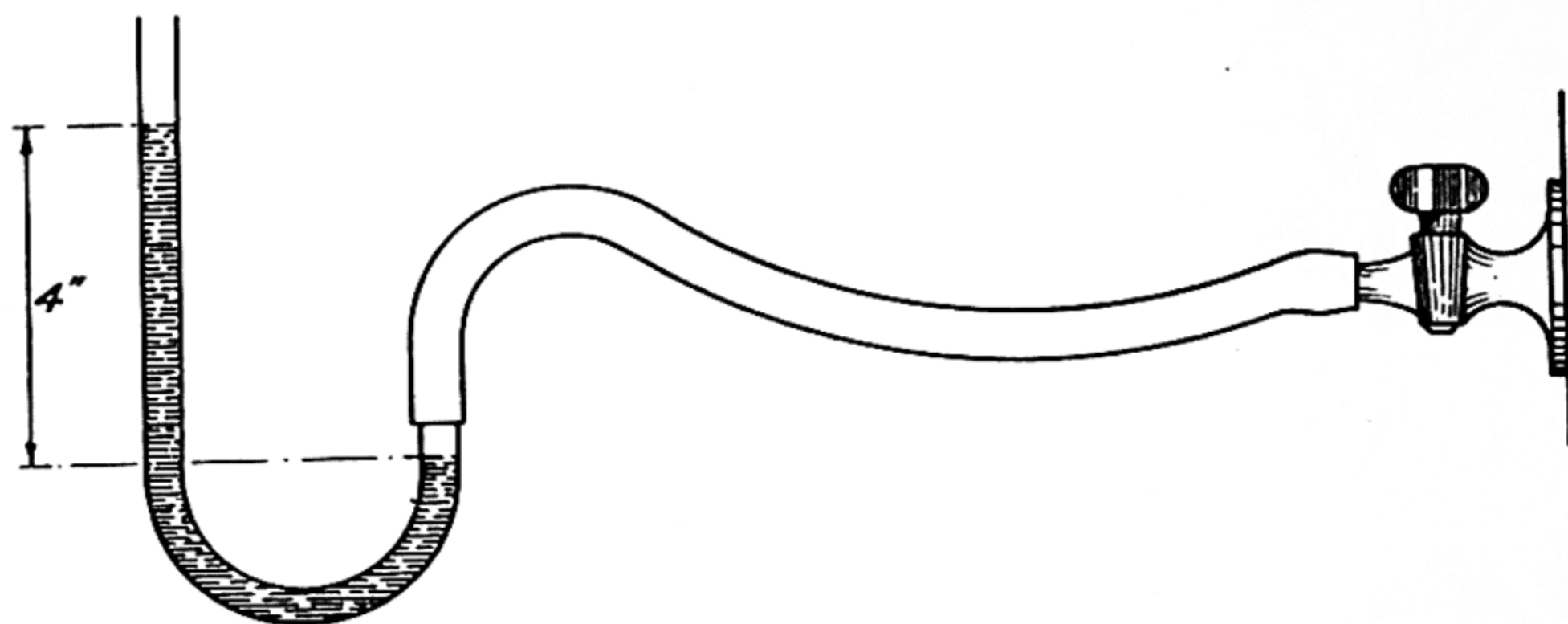


FIG. 4. APPARATUS FOR DEMONSTRATING LOW PRESSURE OF GAS-SUPPLY

the water pressure connect, by means of rubber tubing, a U-tube, with the longer arm about a foot long, to a gas-tap. Place a little water in the U-tube, and turn on the gas. The pressure of the gas

will be equal to the pressure of about 4 inches of water. It will be seen why a plug tap is suitable for holding back the gas, just as similar taps are suitable for wash-boilers and tea-urns.

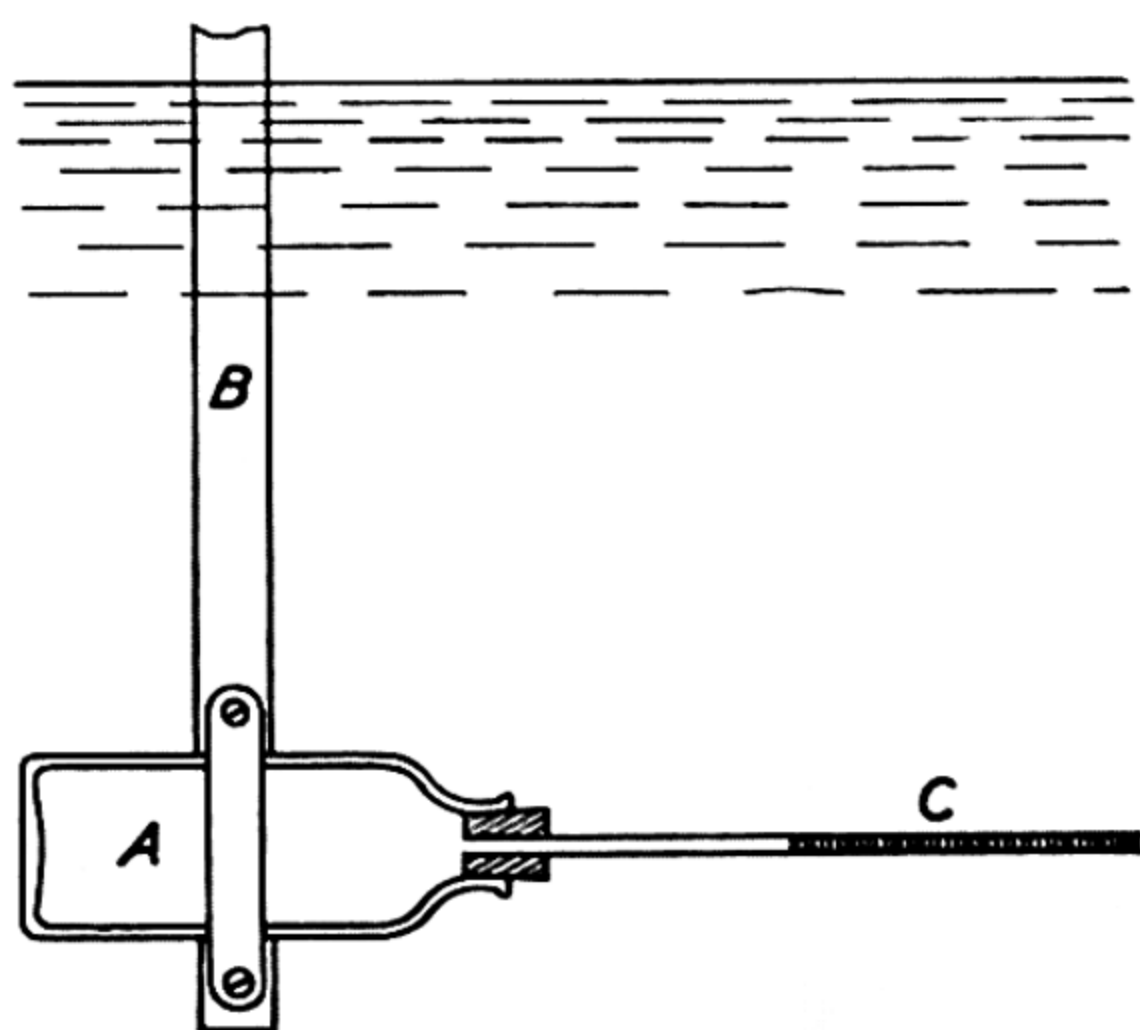


FIG. 5. APPARATUS TO SHOW HOW PRESSURE INCREASES ACCORDING TO DEPTH OF WATER

To show how Pressure increases with Depth in Water

To do this the apparatus illustrated should be immersed in water contained in a large glass tank. *A* is a small bottle fixed to the piece of wood, *B*, with a strip of lead. *C* is a short piece of narrow-bore glass tubing passing through a rubber bung fixed in the neck of the bottle. As this is lowered into the tank water can be seen creeping

along *C* and squeezing the air inside the bottle, just as a diver would be squeezed at great depths if he were not protected by a special diving-suit.

The force of surface tension, and how it holds the water together when anti-splash tap fittings are used, is demonstrated by making the surface tension support a weight by means of a surface-tension balance.

Make a wire frame about 3 in. across from *A* to *B*.

Place a piece of wire across the frame and looped round it so that it can move up and down freely. To this fix with cotton a small piece of thin card. Dip the upper part of the frame, and the wire across it, into a soap solution. Stand the frame upright and the wire will slide down it. Small weights can also be placed on the card.

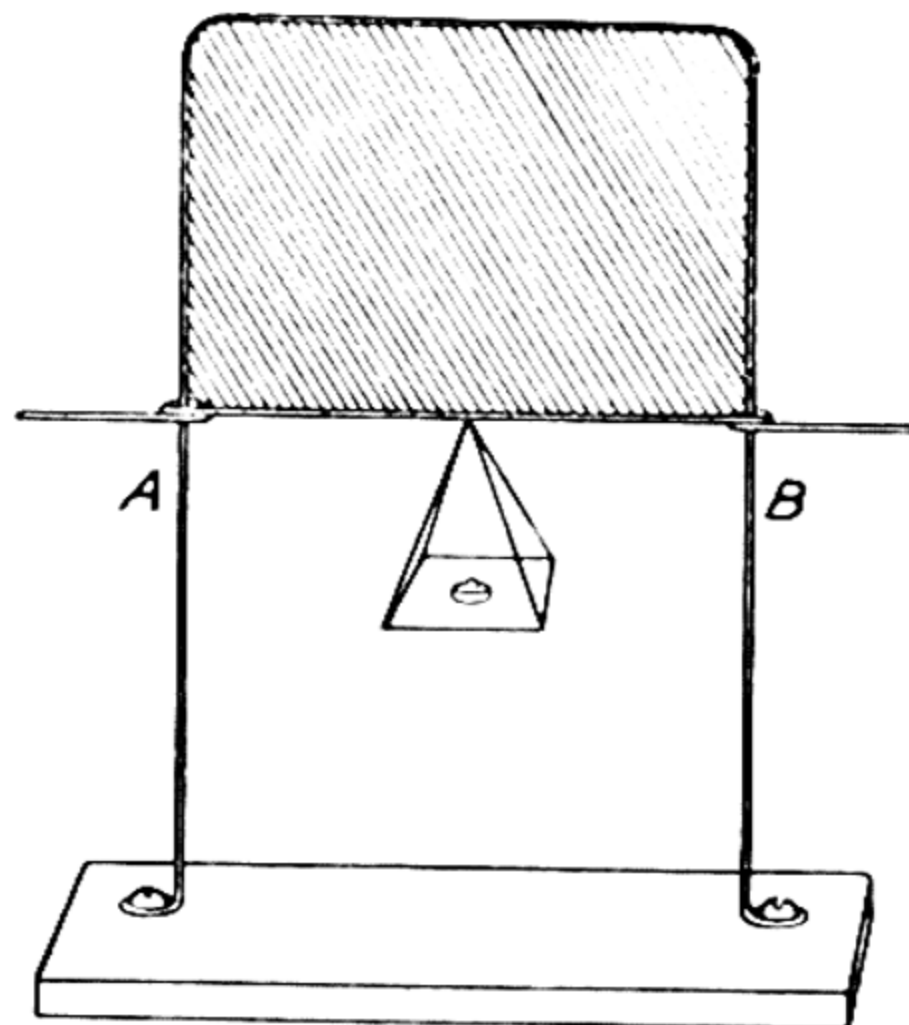


FIG. 6. APPARATUS TO DEMONSTRATE SURFACE TENSION

A Model Ball-tap

A is an empty flask and *B* a piece of stout wire passing through a cork in the neck of the flask. Near the other end of the wire a loop is made. This fits into a

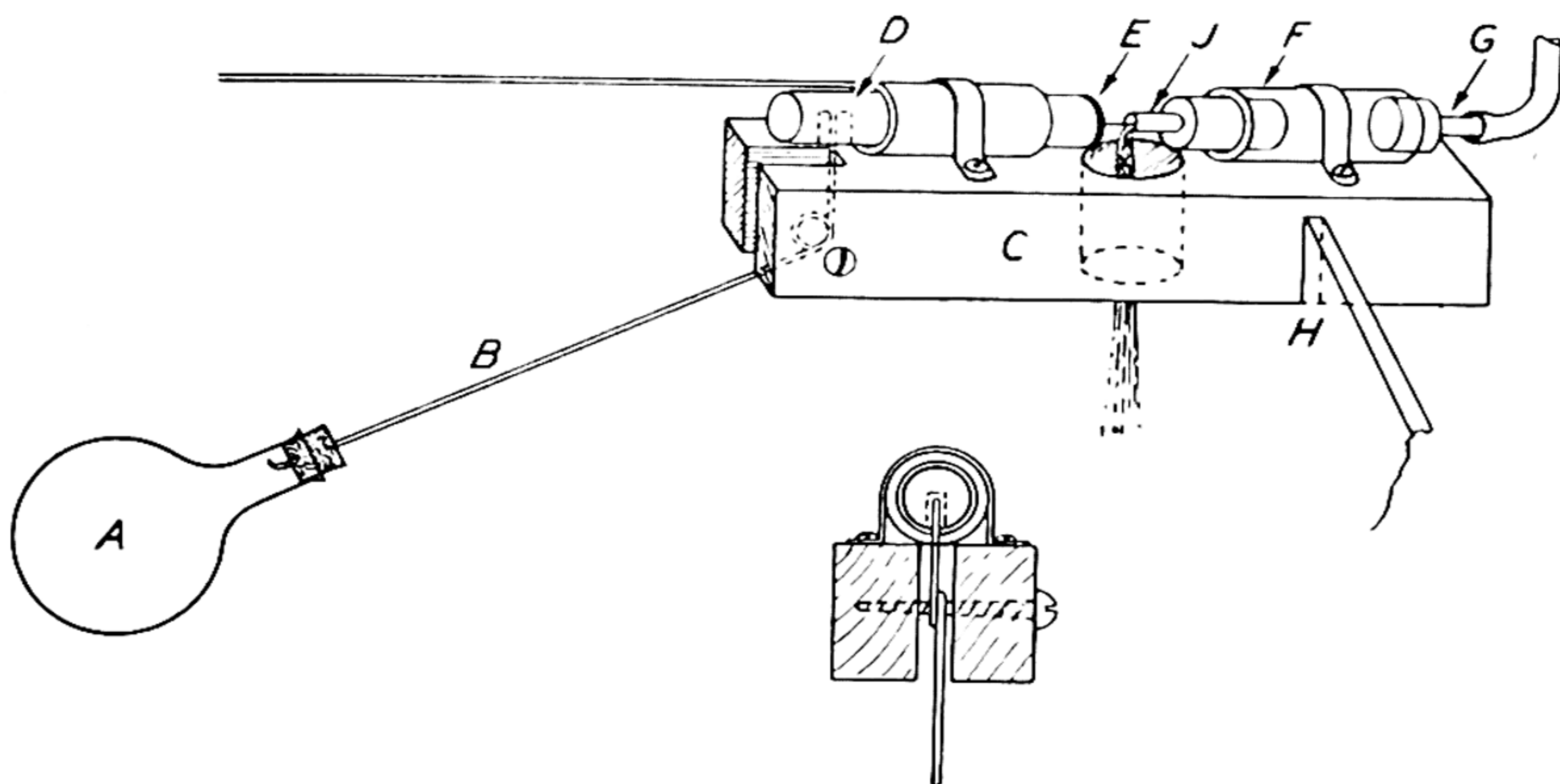


FIG. 7. MODEL BALL-TAP

groove cut from the piece of wood *C*, and it is supported by a screw as shown in the smaller diagram. *D* is a short cylindrical piece of wood, or a short piece of dowelling, which is an easy

sliding fit inside a short piece of glass tubing fixed to the wood *C* with a strip of lead or brass. The end of the wire *B* fits into a hole about a quarter of an inch long cut in *D*. *E* is a piece of sheet-rubber fixed to the end of *D* with small nails. *F* is another short length of glass tubing fixed to *C*, and having corks in each end, through each of which pass short lengths of glass tubing. The piece of glass, *G*, is connected to a water-supply and the apparatus is fixed to the side of a glass tank by means of the groove *H*.

A large tin of water will serve as a water-supply. As the water rises in the tank the flask rises, pushing along *D*, so that the rubber, *E*, presses up against the end of the glass tube, *J*, cutting off the water.

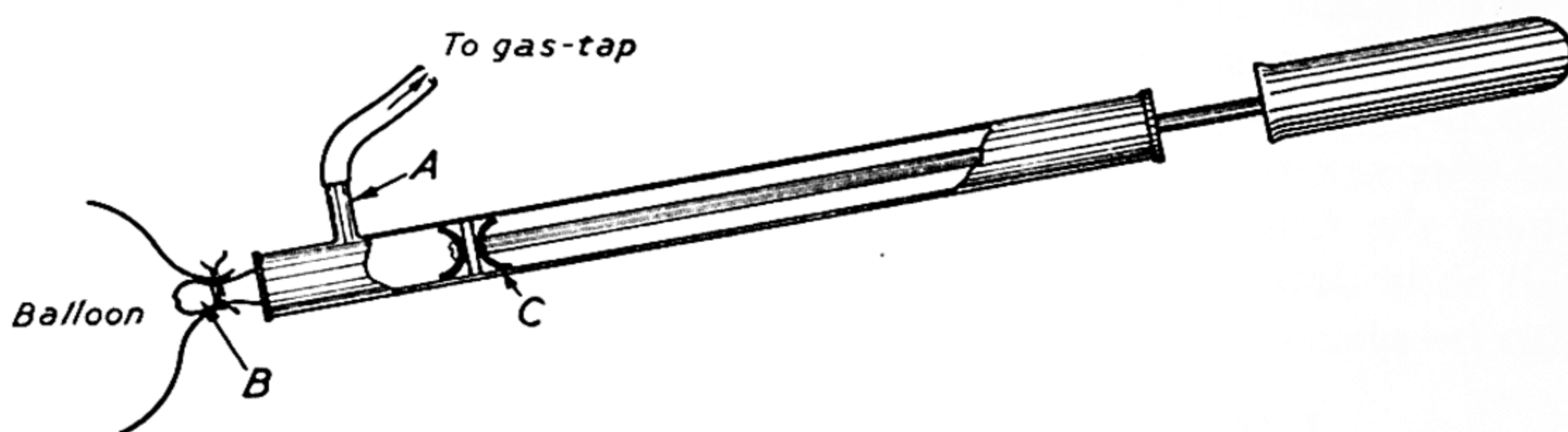


FIG. 8. PUMP FOR INFLATING BALLOONS WITH COAL-GAS

Filling Balloons with Coal-gas

Balloons full of coal-gas will float in air, just as the flask full of air will float in water in the model ball-tap. Ordinary cheap balloons will do, but balloons of good-quality rubber capable of inflation without bursting to 70 in. circumference can be obtained from Messrs Baird and Tatlock, Ltd, 14-17 St Cross Street, Hatton Garden, London, E.C.1. They can be inflated with coal-gas by using a metal bicycle-pump and football-adaptor, *B*, as illustrated. A short length of brass or copper tubing, *A*, is soldered to a small hole drilled near the end of the pump. This tubing is connected to a gas-tap by a length of rubber tubing. An additional leather washer, *C*, is also fitted. On the up-stroke coal-gas is drawn into the barrel of the pump, and on the down-stroke this is forced into the balloon.

A Model Hand-flushing Tank

The examination of an actual hand-flushing tank may be rather confusing to the pupils, as it is impossible to see what is happening inside when the chain is pulled.

Here is a model in which everything that happens can be seen when the chain is pulled. *A* is the same glass tank to which the model ball-tap has been fixed.

Large second-hand glass accumulator tanks can often be obtained from garages for a few shillings. *B* is a block of wood with a piece cut away so that it fits tightly on to the side of the tank, and *C* is a bell-jar with a two-holed cork. *D* is a length of Meccano strip pivoted by means of a screw, *G*. To one end of this strip is fixed a length of string and a wooden handle. Round the other end is fixed a piece of lead to act as a weight, forcing the piston, *L*, back to the bottom of the bell-jar after the handle has been pulled down.

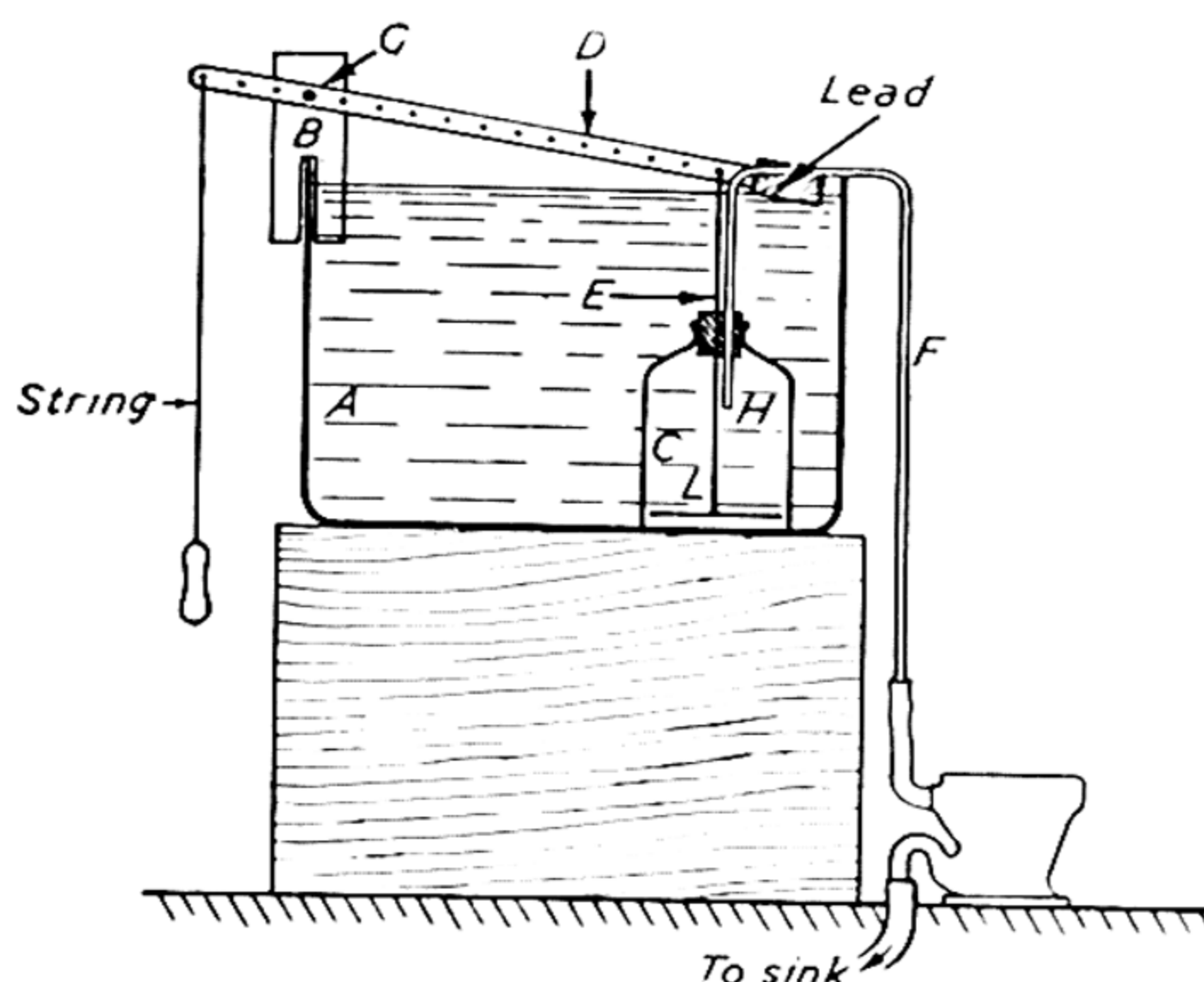


FIG. 9. MODEL FLUSHING TANK

E is a length of stout copper wire, one end of which passes through a hole in the Meccano strip. To the other end is soldered a brass disc which will move up and down easily inside the bell-jar. There should be about $\frac{1}{8}$ in. between the edge of the disc and the inside of the bell-jar. *F* is a wide glass tube. The tank is filled with water, which, when the handle is pulled down, is forced over the bend in *F*. This causes the water to siphon out until the level in the tank falls below the end *H* of the delivery tube. In an actual flushing tank the wide delivery tube *F* passes through a hole in the bottom of the tank. Miniature working-model water-closet basins can be obtained from the manufacturers, A. Johnson and Sons, Ltd, Queenborough, Kent.

Siphons

Two methods of siphoning water from tanks have been described in *Everyday Science Topics*, Book I.

The siphon illustrated here is automatic. To start it the end *A* is pushed quickly into the water. So that the pupils can see what is happening inside this siphon when it is working, it should be made,

in the first place, from glass tubes. Later it can be made from metal tubing.

A hole, *C*, should be made in the glass or metal tube *B*. In a metal tube a hole of about $\frac{1}{8}$ in. in diameter can be drilled.

To make the hole in a glass tube close the end *D* with a rubber bung, get a pupil to blow at the end *E*, and, while he is blowing, concentrate a blowpipe flame on the tube at *C*. When the glass melts the increased pressure inside the tube will cause a hole to form.

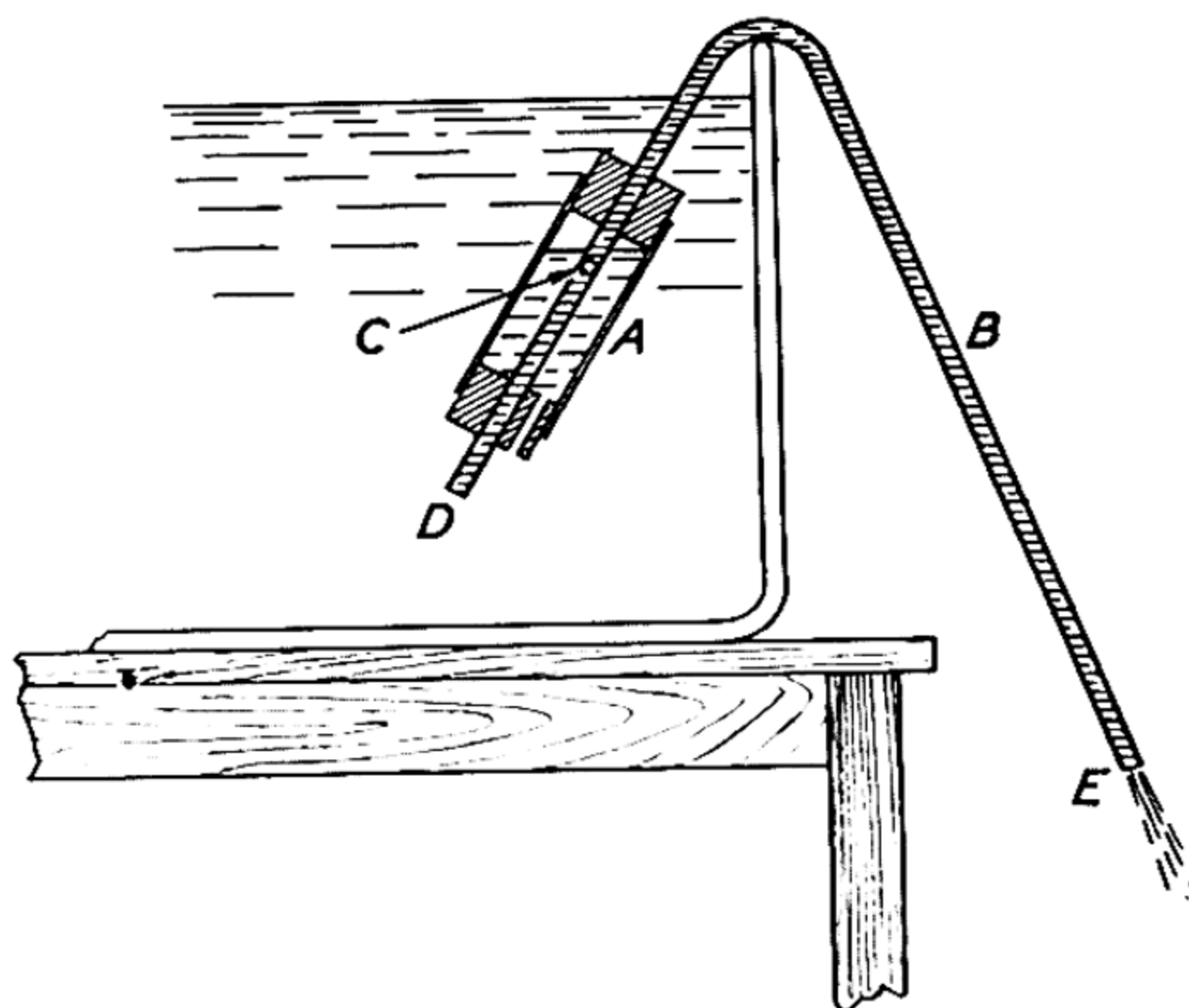


FIG. 10. AUTOMATIC SIPHON

Over the end *D* of the tube *B* must be placed a piece of wider glass or metal tubing about four inches long. This is fixed in position with two rubber bungs, the lower of which has two holes, one for the tube *B* and the other for the water to pass through.

Another Type of Hand-flushing Tank

This is a model of the bell type of hand-flushing tank in use in some parts of the country.

A is the bell-jar with a wide glass tube, *B*, passing through a cork or rubber bung in the neck of the bell-jar. *C* is a large test-tube supported on a wire, and attached by a short wire loop to the end of a Meccano strip. Water should be poured into the bell-jar until it is just below the level of the upper end of the glass tube *B*. Pull the handle down sharply and allow it to go back itself. This will cause the water to siphon down the glass tube. If this flushing tank is tried with the water at various levels in the bell-jar, it will be seen that it is not so reliable as the piston type.

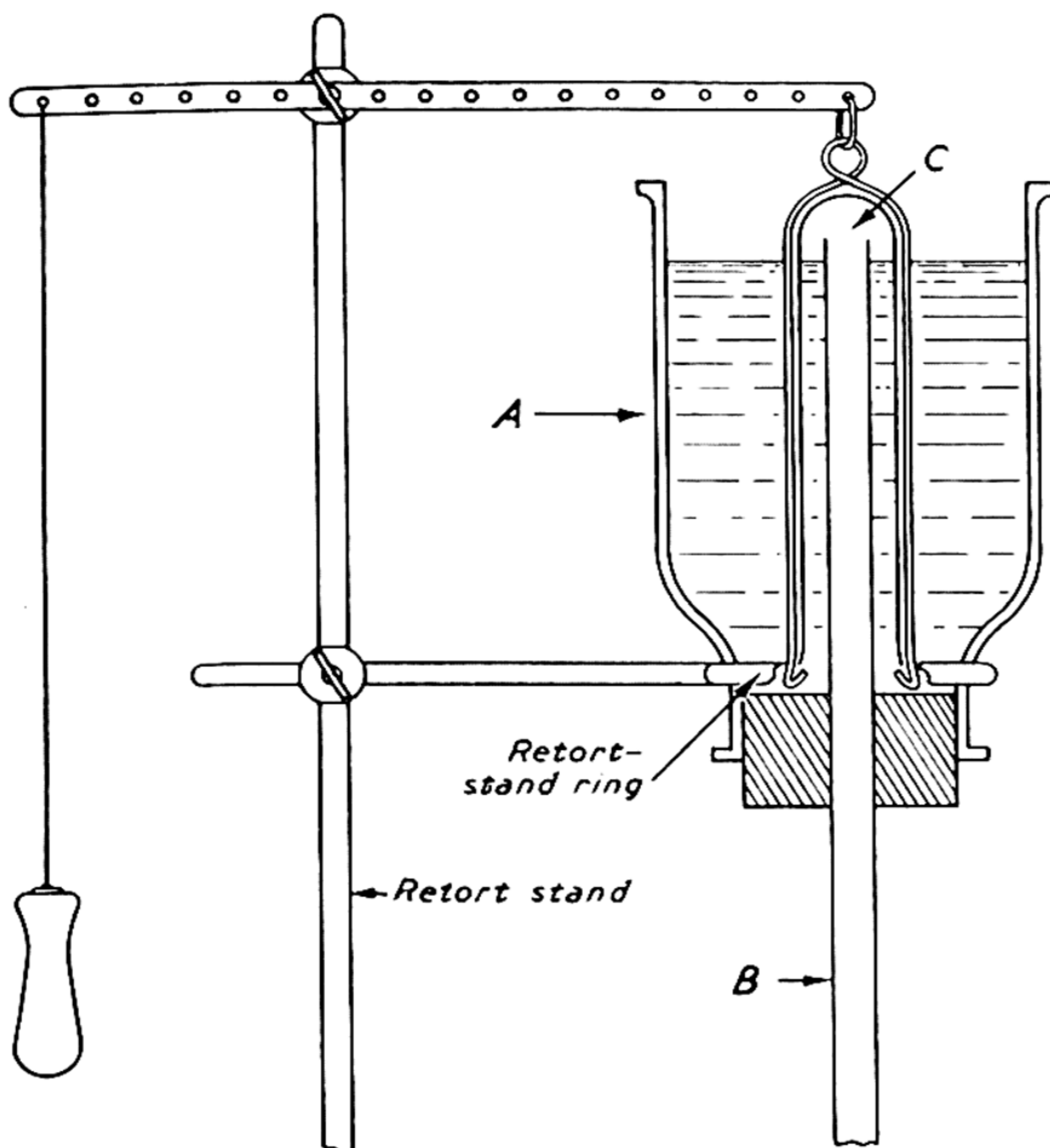


FIG. 11. MODEL BELL-TYPE FLUSHING TANK

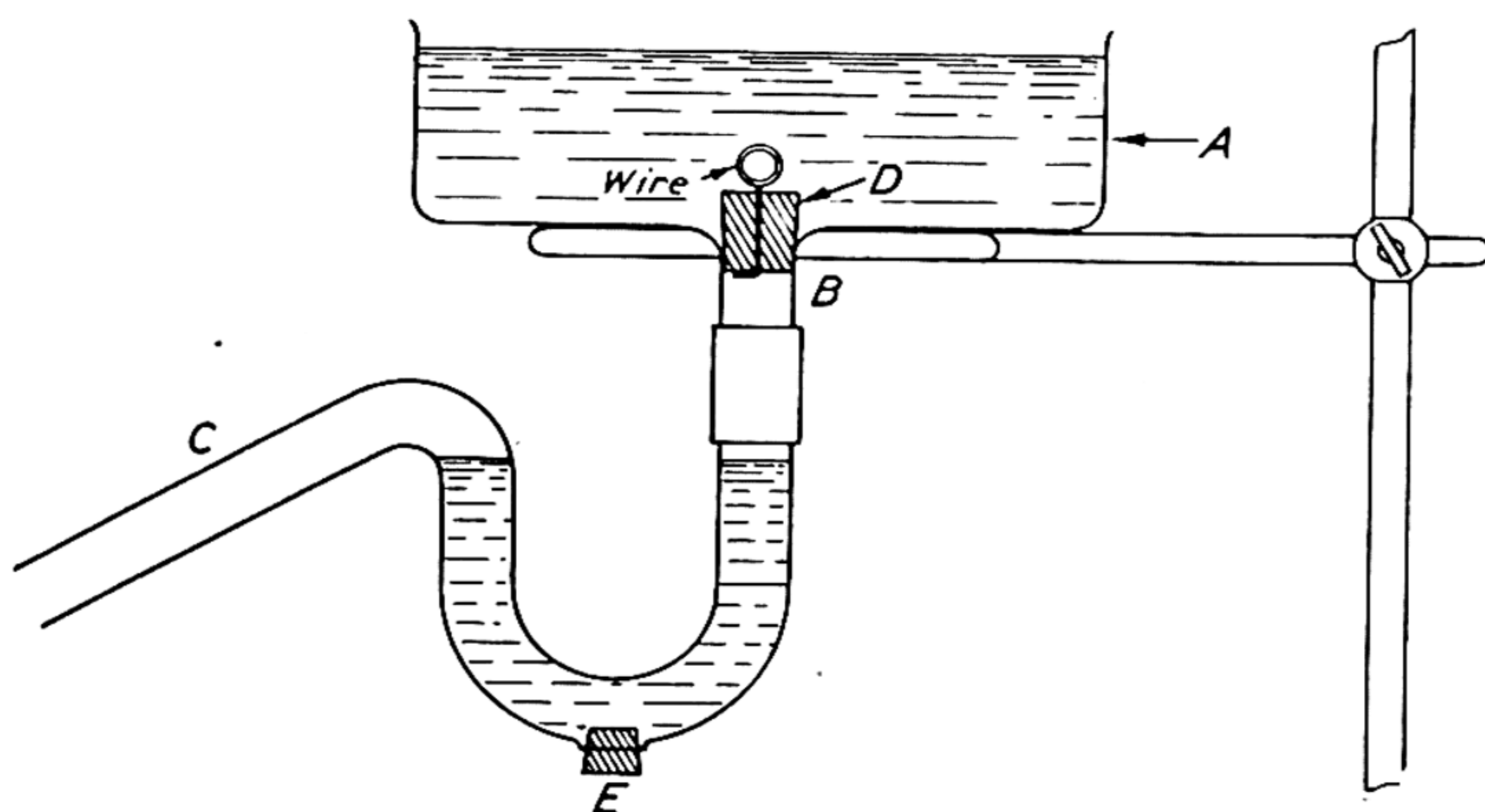


FIG. 12. WATER-TRAP

Water-traps

Pupils will have noticed how water always remains at the bottom of a water-closet basin after it has been flushed. This is called a water-trap, and is to be found in the waste-pipes from sinks, lavatory basins, and baths. A model water-trap, which shows how they work and how they can be cleaned out if they become blocked, is illustrated.

A is a shallow tin which serves as a sink. A hole is made in the bottom of this and a short piece of brass or copper tubing, *B*, is soldered over the hole. A length of glass tubing, *C*, is bent in a batswing flame to the shape shown, and a hole is made in the bottom of the U-shaped part of the tube as described for the automatic siphon. A rubber bung is placed in this hole. The bung *D* acts as a sink-plug.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

- ADLAM, G. H. J. (Editor): *The Science Master's Book*, Series I, Part I.
 ANNISS, F.: *The New Practical Physics*, Books I and II.
 BEAN, H. E.: *Everyday Science*, Books II and III.
 DE RATTI, A.: *Simple Scientific Experiments* ("Model Engineer" series).
 DUCKWORTH, E. H., AND HARRIES, R.: *The Laboratory Workshop*.
 LITTLE, W. B.: *General Elementary Science and Science in the Home*.
 LOW, A. M.: *Popular Scientific Recreations*.
 MACDOUGALL, A. T.: *Nature's Giant Forces and Nature's Wondrous Laws*.
 RAY, C. (Editor): *The Boy's Book of Popular Science*.
 SCARR, W. A.: *Science in Common Things*, Book I.
 WAY, E. B.: *From Log to Liner*.
 WHIPPLE, A. H.: *Hygiene of the Home*.
 WHYTE, A. G.: *Divers and Diving*.

See also pp. 13–26 of *Everyday Science Topics*, Book I.

Films

- A Drink of Water* (16 mm., silent, 1 reel¹) (Wallace Heaton, Ltd).
Ocean Liners (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).
Sewage Disposal (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).
Surface Tension (16 mm., sound, 2 reels) (British Instructional Films, Ltd).
Water Levels (16 mm., silent, 2 reels) (Educational and General Services, Ltd). (The principles of the household water-supply explained diagrammatically.)
Water Service (16 mm., sound, 1 reel) (Central Film Library).

¹ Throughout this book a 'reel' means a 400-ft. reel—sound film, 10 min. silent film, 15 min.

Film-strips

Flotation (Unicorn Head, Ltd).

Household Plumbing (Army Kinema Corporation).

Sewerman (Common Ground, Ltd).

The Making of Brass Taps (Unicorn Head, Ltd).

Water (Visual Information Service).

Water on Tap (British Instructional Films, Ltd).

Water Taps, Pipes, and Cisterns (Common Ground, Ltd).

Other Visual Aids

Set of twelve charts on plumbing (Educational Productions, Ltd).

Visual Book, *Water in your Home* (Educational Productions, Ltd).

(B) Electricity in the Home

While working on this topic pupils and teacher should try to collect together in the science room samples of all the appliances to be mentioned. A good selection of electric bells, buzzers, bell-pushes, bell-indicators, cells, and batteries should be available. They can often be obtained at little cost from various sources. Pupils may have old appliances at home, and much useful second-hand apparatus can often be obtained from local sale-rooms, garages, and electrical contractors. Manufacturers will often send samples and illustrated literature. The electrical apparatus sold by the cheap stores is quite suitable for school work.

A Coil-winder

Coils of insulated wire (solenoids) of different sizes and with various numbers of turns of wire are required for experiments in connexion with electro-magnets for making model electric bells and buzzers, bell-indicators, electric hooters, motor-car indicators, transformers, ammeters, etc. Winding these coils by hand takes a long time and is very fatiguing, and invariably the winder loses count of the number of turns he has completed.

By means of the coil-winder illustrated solenoids of various sizes can be made quickly and easily; the revolution counter registers the number of turns completed. The formers for the solenoids can be made in either of the ways illustrated. These can be held rigidly in the coil-winder by pushing the two wooden cones tightly together and fixing the set screws in the Meccano bush wheels screwed to the bases of the cones. The revolution counter can be purchased from Electradix Radios, 214 Queenstown Road, London, S.W.8, and the cyclometer bracket from a cycle-dealer.

The numbers on the illustration are the catalogue numbers of

Meccano parts used. A catalogue of Meccano parts is most useful, and can be obtained from a local dealer. There should be a special box in which boys can place any Meccano parts they no longer require.

The coil-winder should be clamped to the bench when in use, and one pupil should turn the handle while another manipulates the

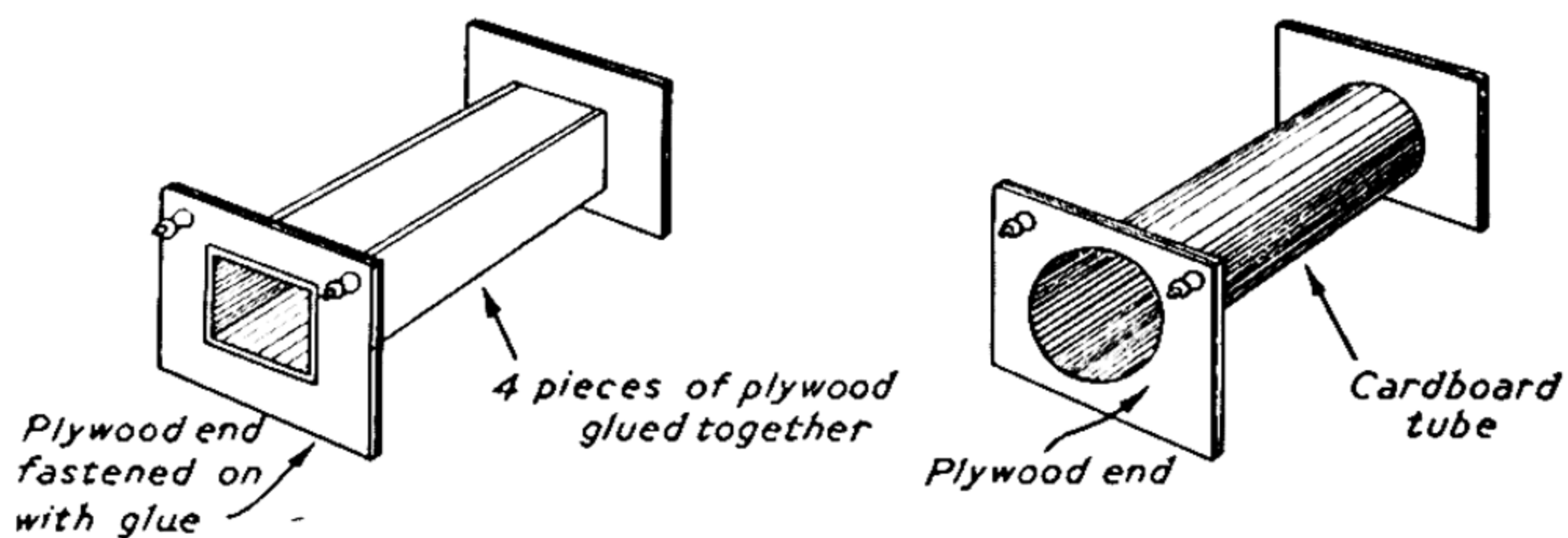
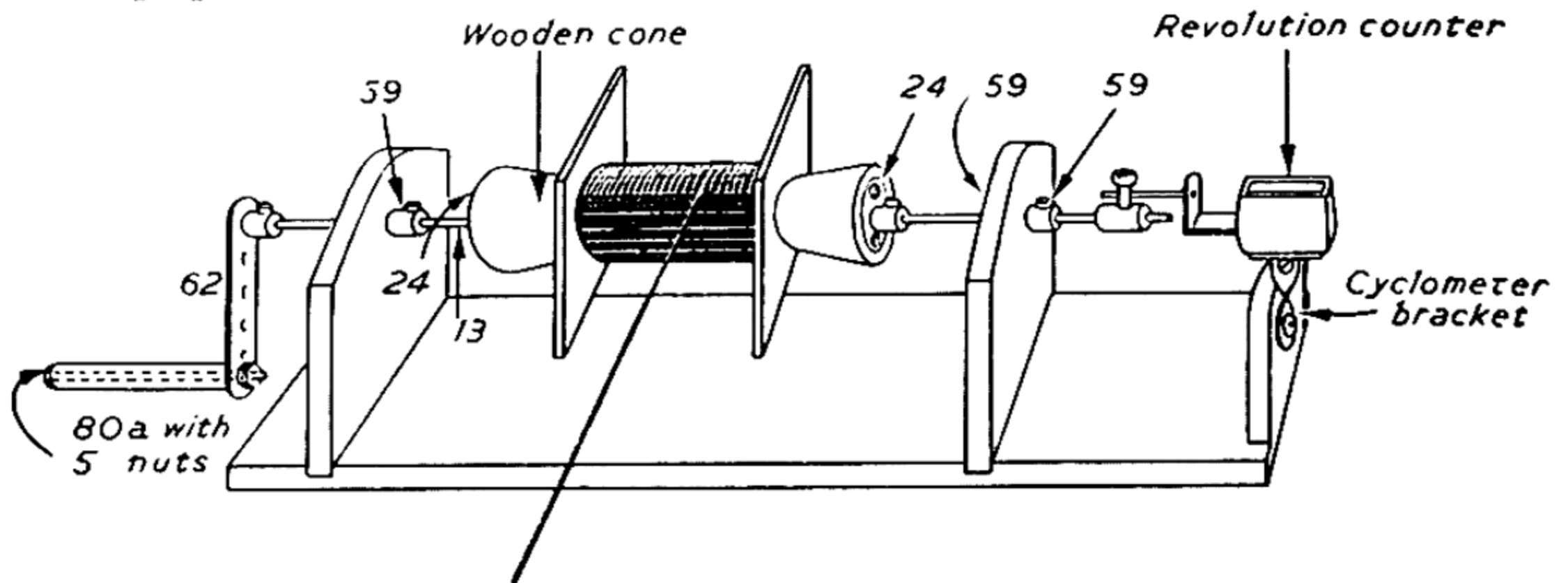


FIG. 13. COIL-WINDER

wire. A third pupil should hold the bobbin of wire on a pencil so that it can revolve freely.

To show how the Strength of an Electro-magnet depends on the Number of Turns of Wire, the Strength of the Current, and the Type of Core

Apparatus for these experiments is illustrated in Fig. 14. The solenoids are made as previously described and connected to the vertical board by means of Electrano parts, so that they can be quickly disconnected and used for other purposes. Electrano parts are referred to many times in these books. They can be put to all kinds of uses, and are obtainable from the Electrano Co., BCM/Electrano, London, W.C.1.

The solenoids are connected in series so that the same current passes through both. The current strength can be increased by

increasing the number of cells or by using a higher voltage tapping on the distribution board or potentiometer, described in Chapter IV.

To examine the effects of using compound and solid cores, the faggot binding-wire cores can be replaced by lengths of $\frac{3}{8}$ -in. diameter soft iron rod.

The strengths of the electro-magnets under the various conditions can be measured by noting the number of half-inch lengths of $\frac{1}{8}$ -in. diameter soft iron wire which can be suspended from the cores.

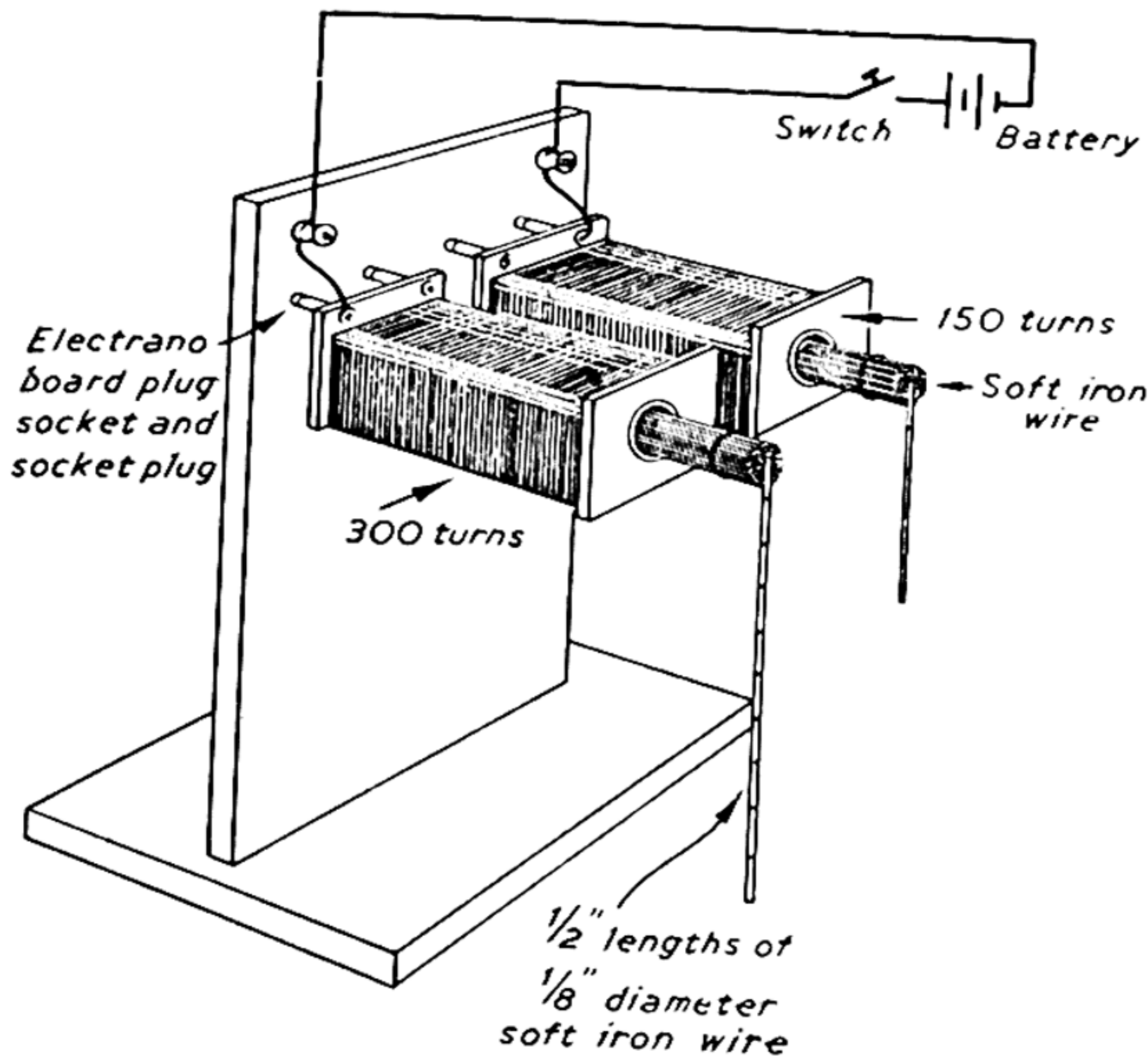


FIG. 14. APPARATUS FOR DEMONSTRATING STRENGTH OF ELECTRO-MAGNET

A Model Crane Magnet

Quite a small magnet of this type will lift heavy pieces of iron or steel. *A* is a hollow cylindrical piece of soft iron and *B* is a piece of cylindrical soft iron rod. *C* is a circular iron plate with holes drilled in it to allow the screwed rod *D* and the small bolts *E E* to pass through. *A* and *B* are tapped to take the small bolts and the screwed rod *D*. *F* is an ebonite or plywood disc having two terminals and held in position on *D* with nuts. The space between the iron rod *B* and the outside cylinder *A* is completely filled with No. 26 D.C.C. wire. The method of placing this wire in position is illustrated in (b).

A coil-former is built up with a piece of dowelling equal in length and diameter to *B*. Circular pieces of plywood are placed on the ends of this dowelling, and the wire is wrapped on this former until

there is just enough to fill the space between *A* and *B*. The ends of this wire are then pushed through holes drilled in *C* and joined to the terminals. One circular piece of plywood is carefully removed, the end of the dowelling is placed near the end of the iron rod *B*, and the other circular plywood disc is used to push the wire into position and is then removed. The wire is then sealed in position with hot paraffin wax.

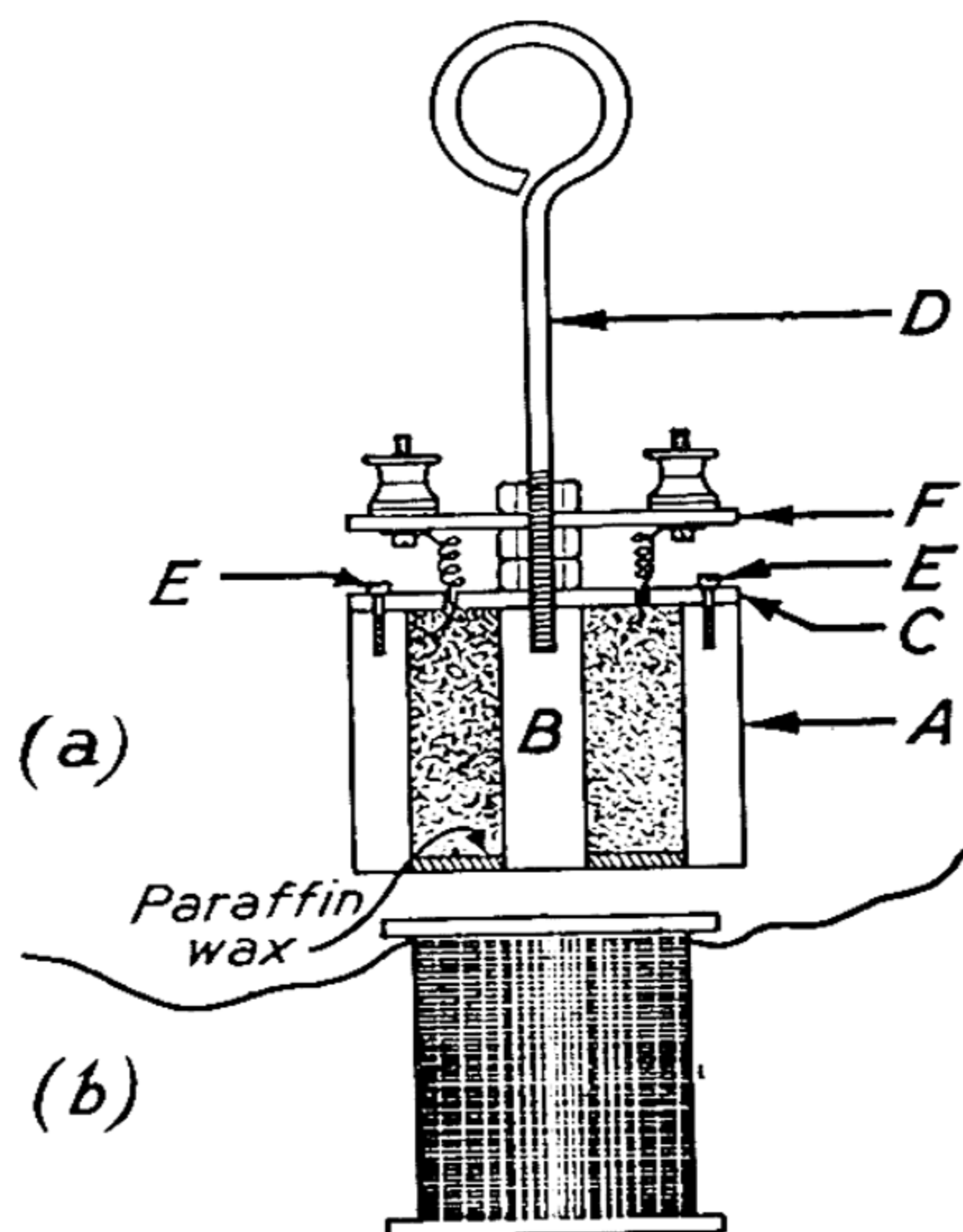


FIG. 15. MODEL CRANE MAGNET

Miniature Leclanché cells can be constructed, as illustrated, by carefully removing from worn-out cells the zinc and the carbon rods, with their surrounding black powder left intact in the muslin bags,

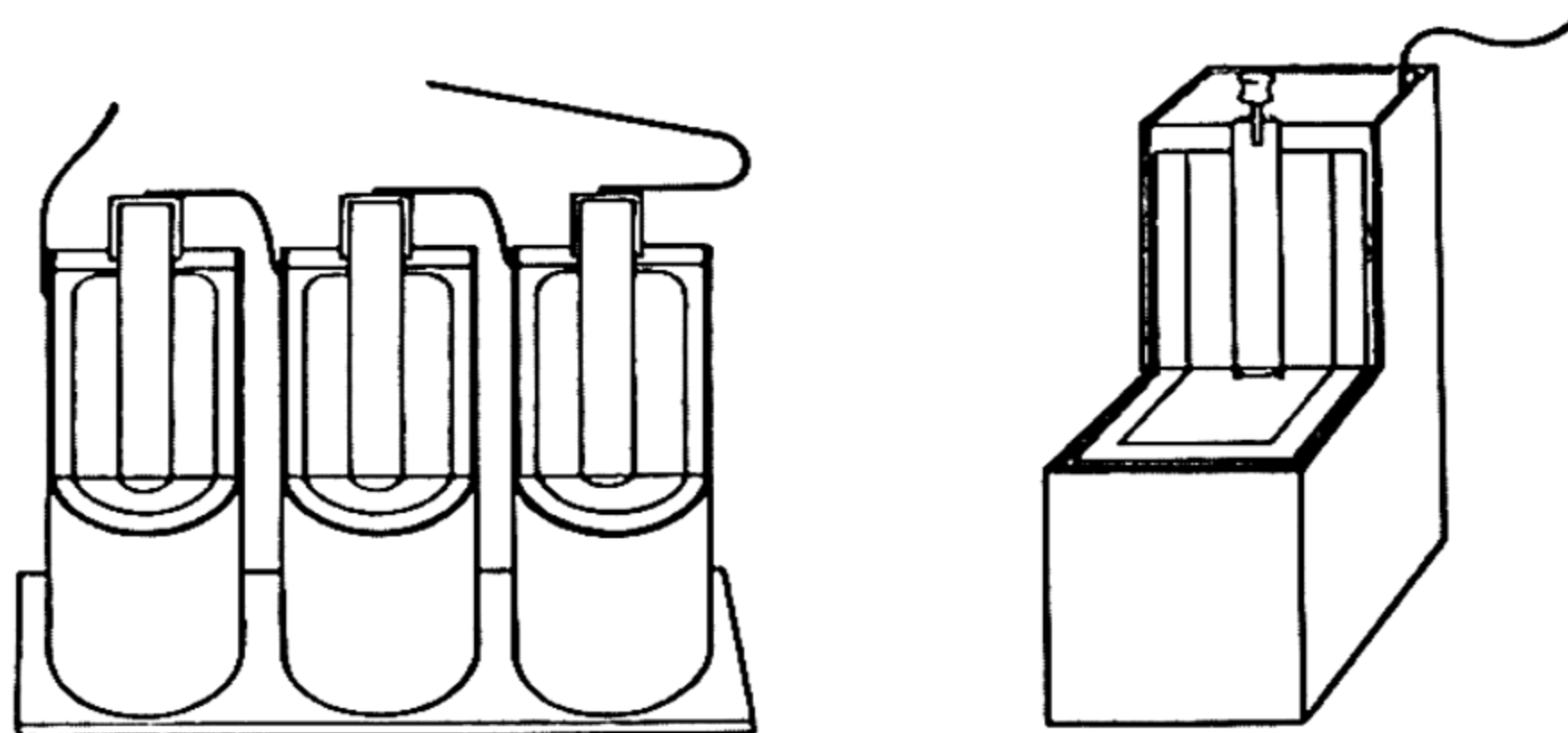


FIG. 16. BATTERY AND CELL SAWN IN HALF

and placing these in small glass jars containing ammonium chloride solution. The zinc cases from these old cells can easily be removed

Cells and Batteries

Teachers should collect samples of the many different types of cells and batteries even though they may be quite used up.

An excellent way of teaching what the inside of a cell or battery is like is to cut them in half with a hack-saw. During the sawing they should be held firmly in a vice. The porous pot from an old Leclanché cell can be sawn in the same way to show its interior construction.

by cutting them along the joints with an old knife. One worn-out 120-volt high-tension battery will supply 80 cells for this work.

When Leclanché cells are purchased there is no need to buy complete cells. Only the porous pots and zinc rods are required, as these can be placed in ammonium chloride held in large jam-jars. The upper parts of the jars should be painted black outside.

A Battery of Simple Cells

This battery consists of four small glass jars in each of which is placed a little ammonium chloride solution, and a piece of zinc and a carbon rod taken from old cells. If you remove the carbon rods from the old cells carefully you will find a short piece of wire soldered to the brass cap on the top of each carbon rod. This should be joined by means of a crocodile clip to the zinc in the next cell. The first piece of zinc and the last carbon rod are joined by insulated wire to a home-made switch and 3.5-volt lamp.

When the key is pressed the lamp lights up brilliantly, but almost

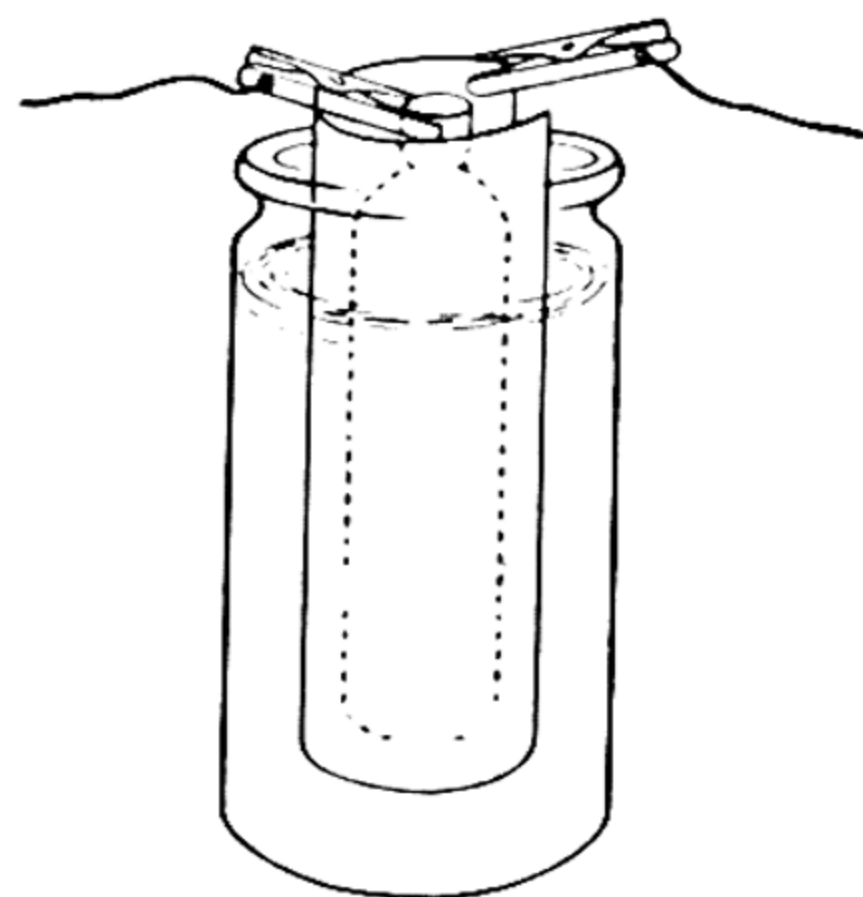


FIG. 17. MINIATURE
LECLANCHÉ CELL

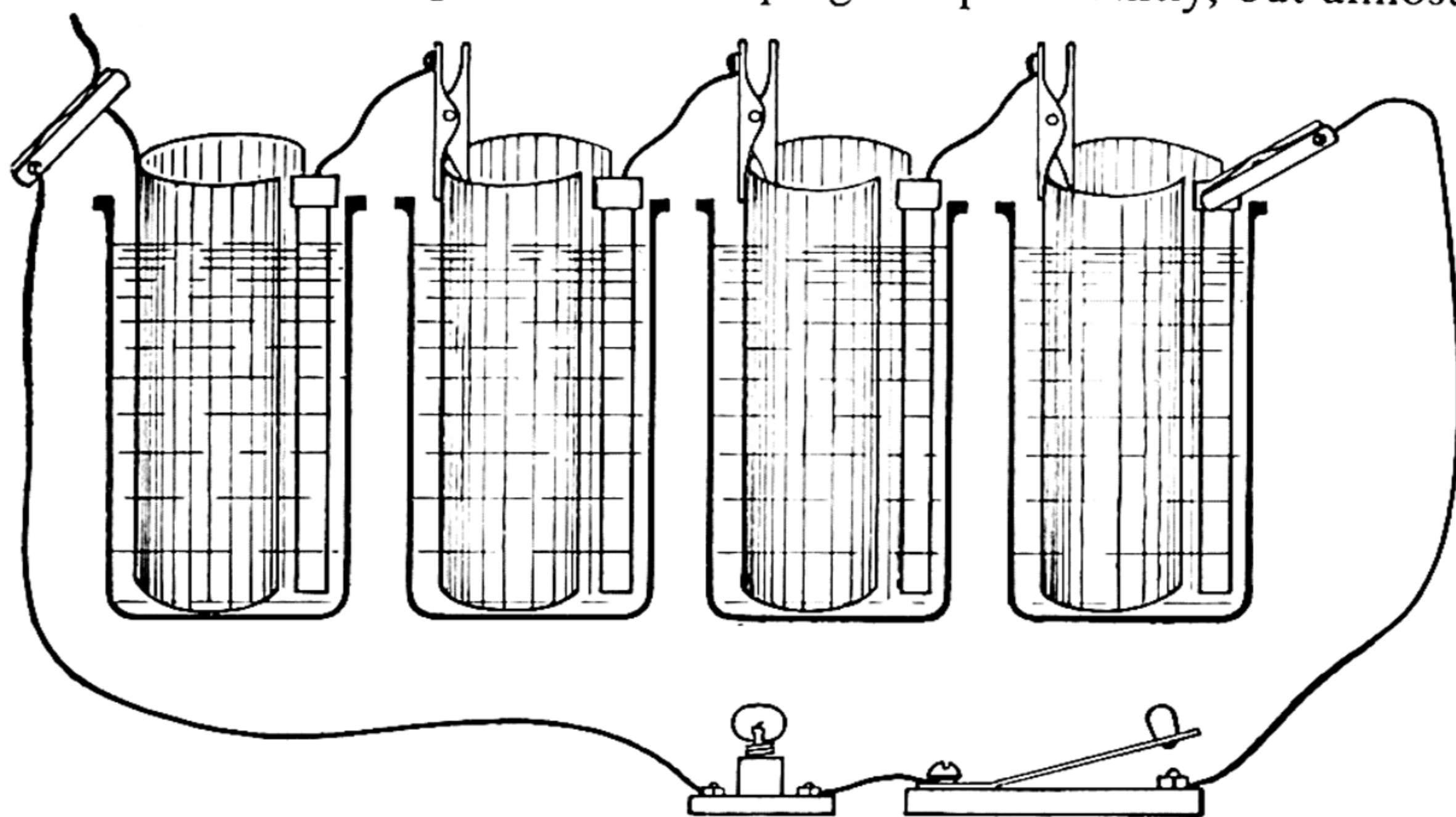


FIG. 18. SIMPLE-CELL BATTERY

immediately the light grows dim and soon goes out altogether. Bubbles of gas can be seen collecting on the carbon rods. This is called polarization, and the black powder round the carbon rods is

intended to prevent this. The carbon rods should now be removed, and carbon rods with their surrounding black powder contained in muslin bags placed in the jars. When the key is pressed the lamp lights up brilliantly and remains brilliant.

An excellent way to make this battery portable is to pack sawdust round the zinc and muslin bag and keep this moist by pouring in ammonium chloride solution from time to time. The jars can be fixed in a small wooden box with two terminals, and in this way you will have a very effective and cheap battery. The pieces of zinc will need replacing occasionally.

Further Information

Other experiments and models and further information are contained in the following books, details of which are given in Chapter VII.

BEAN, H. E.: *Everyday Science*, Book II.

DAVIES, S. J., AND KENNEDY, T.: *Electrical Experiments for Schools and Colleges*.

DUCKWORTH, E. H., AND HARRIES, R.: *The Laboratory Workshop*.

JOHNSON, V. E.: *Electrical Recreations*.

LOW, A. M.: *Popular Scientific Recreations*.

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book II.

MACDOUGALL, A. T.: *The Wonders of Electricity*.

MARSHALL, P. (Editor): *Electric Batteries* ("Model Engineer" series).

MARSHALL, P. (Editor): *Simple Electrical Working Models* ("Model Engineer" series).

MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.

RANDELL, W. L.: *The Romance of Electricity*.

RAY, C. (Editor): *The Boy's Book of Popular Science*.

WHITE, W. B., AND WATSON, T.: *Handicraft in the Senior School*.

See also pp. 27-45 of *Everyday Science Topics*, Book I.

Films

Battery and Dynamo, Part I (16 mm., sound, 1 reel) (Army Kinema Corporation).

Current Electricity (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Magnetic Effects of Electricity (16 mm., silent, 1 reel) (Wallace Heaton).

On Electric Currents and Circuits (16 mm., silent, 1 reel) (Dance-Kaufmann Technical Films).

Dance-Kaufmann 16 mm. Cycle Films: No. 8e, *The Electric Bell*; No. 1063, *Galvani's Frog Experiment*.

What is Electricity? (16 mm., sound, 1 reel) (Elec. Devel. Assoc.).

Magnetism (16 mm., sound, 1 reel) (Elec. Devel. Assoc.).

Film-strips

Electricity in the Home (Common Ground, Ltd).

History of Electricity (Common Ground, Ltd).

Simple Electric Circuit (Common Ground, Ltd).

Miscellaneous

The catalogues issued by Electradix Radios, Ltd, 214 Queenstown Road, London, S.W.8, and the Economic Electric Company, 64 London Road, Twickenham, contain details of much helpful apparatus in connexion with this topic.

The Electrano Electrical Plug Board Apparatus is also very useful. Bells, buzzers, bell-pushes, bell-indicators, etc., can be mounted on small wooden baseboards and plugs fixed to the boards so that the apparatus can be quickly connected upon a vertical or horizontal board and the path of the current is clearly visible to the pupils. Details of this apparatus can be obtained from the Electrano Company, BCM/Electrano, London, W.C.1.

(C) Water-supply and Water-power

Much of the information contained in this section can be adapted and modified for use in districts where the water is not obtained from a near-by river.

A large-scale map of the district showing the position of the waterworks, the chief distribution pipes and reservoirs, together with a large-scale plan of the works should be on exhibition in the science room. On the district plan should be marked the altitude at the reservoirs, at the works, and at various places on the distribution pipes. The superintendent of the waterworks will usually supply all information necessary.

After a preliminary lesson on this topic the pupils should visit the works with the science teacher. Work on the topic will then be completed much more intelligently. During the visit to the works samples of the water at various stages can be collected for exhibition in the laboratory. The points at which the samples were collected should be indicated on the works plan. The pupils can also take readings at the various meters. These readings provide a basis for interesting numerical work later.

A water-meter may usually be borrowed for exhibition in the science room by making application to the waterworks superintendent, and the head-pressure gauge sold by Messrs Ideal Boilers and Radiators, Ltd, Hull, is excellent for measuring the water pressure at the taps. Moreover, the gauge can be dismantled to show its construction.

Messrs Bassett-Lowke, Ltd, Northampton, sell a model pumping set, including electric motor and pump, and sets of parts for constructing model centrifugal pumps. Details of these are given in their catalogue of scale-model engines.

The purifying action of chlorine can be demonstrated by passing it into a sample of pond-water fairly rich in the lower forms of

pond-life. The pupils should be shown a sample of this water on the micro-projector before and after passing in chlorine.

The action of settling tanks can be demonstrated by shaking up a sample of muddy water and then allowing it to settle. The action of the filters can be demonstrated by pouring some of the muddy water into a funnel filled with small shingle and fine sand. The muddy water should have a fair amount of dirt in suspension, and the funnel should have a piece of muslin over the exit.

The superintendent of the waterworks may also be able to obtain from the manufacturers of the filters used at his works a large diagram showing what the filters are like inside.

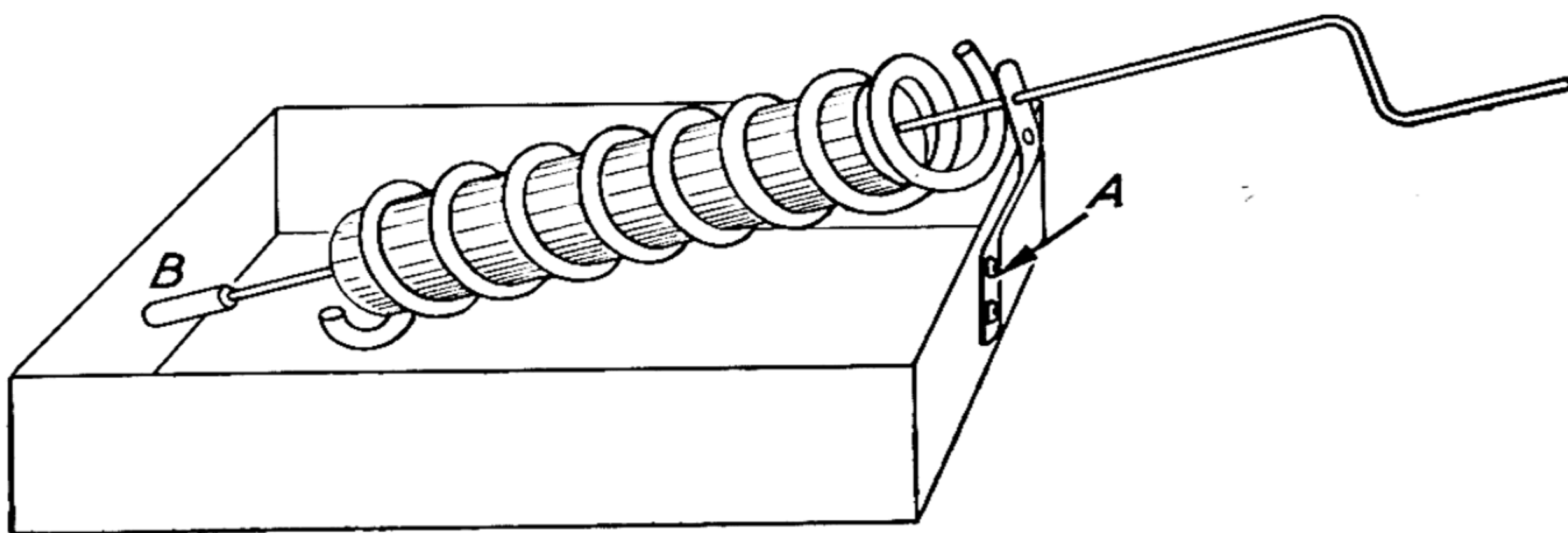


FIG. 19. MODEL ARCHIMEDEAN SCREW

The Economic Electric Company's catalogue gives details of motor-driven pumps and water-turbines which can be worked from the water-tap.

The importance of removing from water certain substances in solution and how settling tanks and filtration fail to do this should be mentioned. The method of doing this by distillation in the laboratory can be demonstrated, and it will be seen that this is impossible for large quantities of water at the waterworks. It can then be shown how this is done by adding to brownish-coloured river-water small quantities of solution of alum and sodium aluminate before it passes to the settling tanks and filters. This makes the water clear. These solutions will make even inky water clear, the substances in solution being rendered insoluble so that filtration will remove them.

Particulars of water-meters may be obtained from the manufacturers (George Kent, Ltd, Luton, or the Leeds Meter Company, Ltd).

Archimedean Screw for raising Water

This model always arouses much interest, and can be used in connexion with discussions on the development of methods of raising water.

The trough consists of a shallow cake- or biscuit-tin, which should be painted inside and out to prevent rusting. The spiral is made of $\frac{1}{4}$ -in. diameter copper tubing, which can be pulled into shape round a wooden cylinder about $1\frac{1}{2}$ in. in diameter and held at one end in a vice. The axle and handle are made of $\frac{1}{8}$ -in. diameter brass rod, which passes through a length of Meccano strip, *A*, fixed to one end of the trough with Meccano nuts and bolts and then through the centre of the wooden cylinder which holds the spiral tube. This wooden cylinder is part of the cylinder on which the spiral was formed. The other end of the rod rests in a length of brass tubing, *B*, which is soldered to the inside of the other end of the trough.

The trough should be partly filled with water so that the open end of the spiral tube dips into the water each time it is turned.

How Pumps work

A is a cylindrical glass lamp-chimney, or a piece of wide glass tubing, both ends of which are closed with corks or rubber bungs.

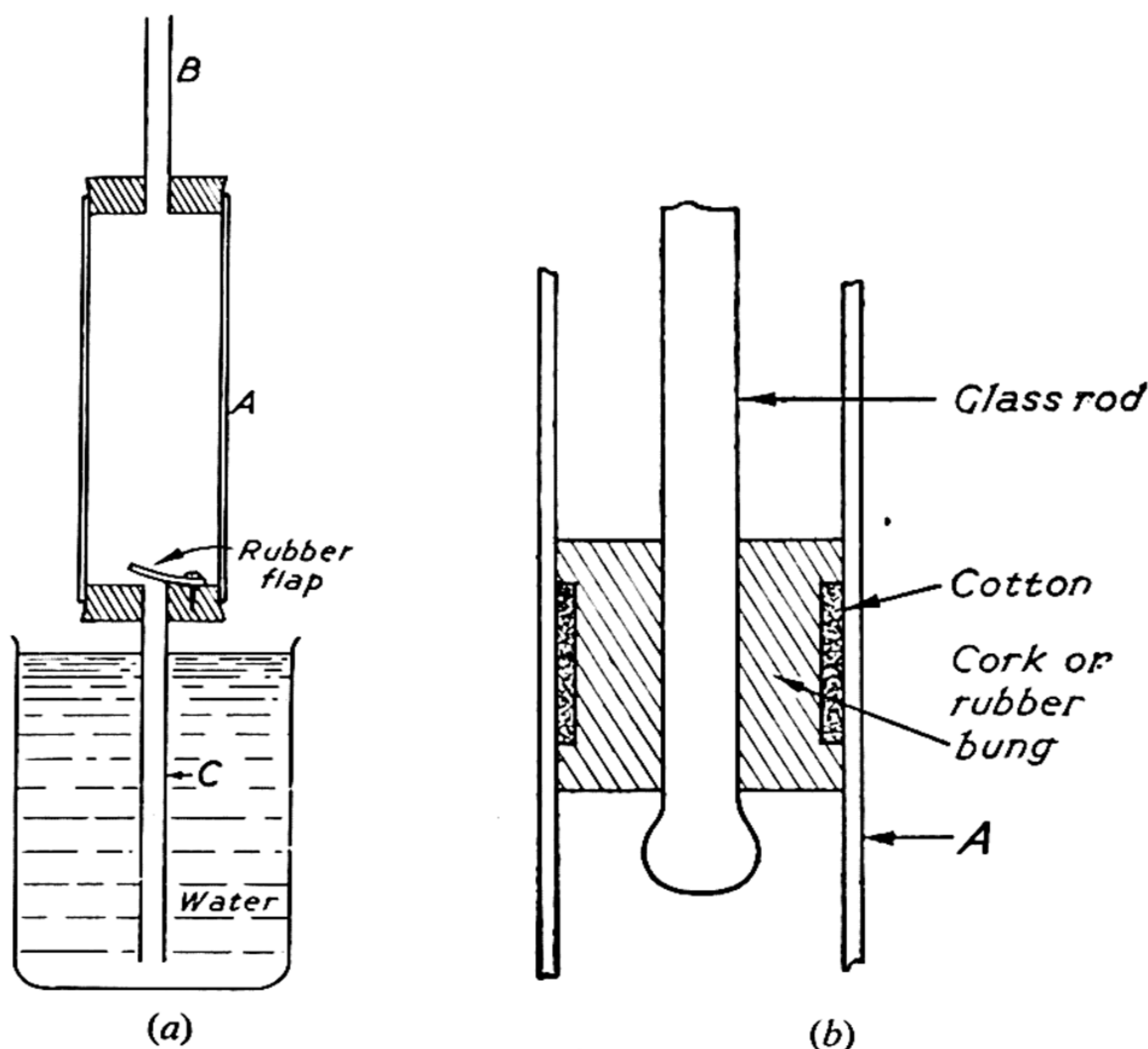


FIG. 20. THE PRINCIPLE OF THE PUMP

If corks are used it may be necessary to seal them in position with paraffin wax. *B* and *C* are glass tubes. If the air pressure inside the

lamp-chimney is decreased by sucking out air with the mouth the water rises into the chimney or tube and is prevented by the valve from flowing out.

The upper cork and tube *B* should be removed and a piston made to fit inside the lamp-chimney or tube as shown in Fig. 20 (b).

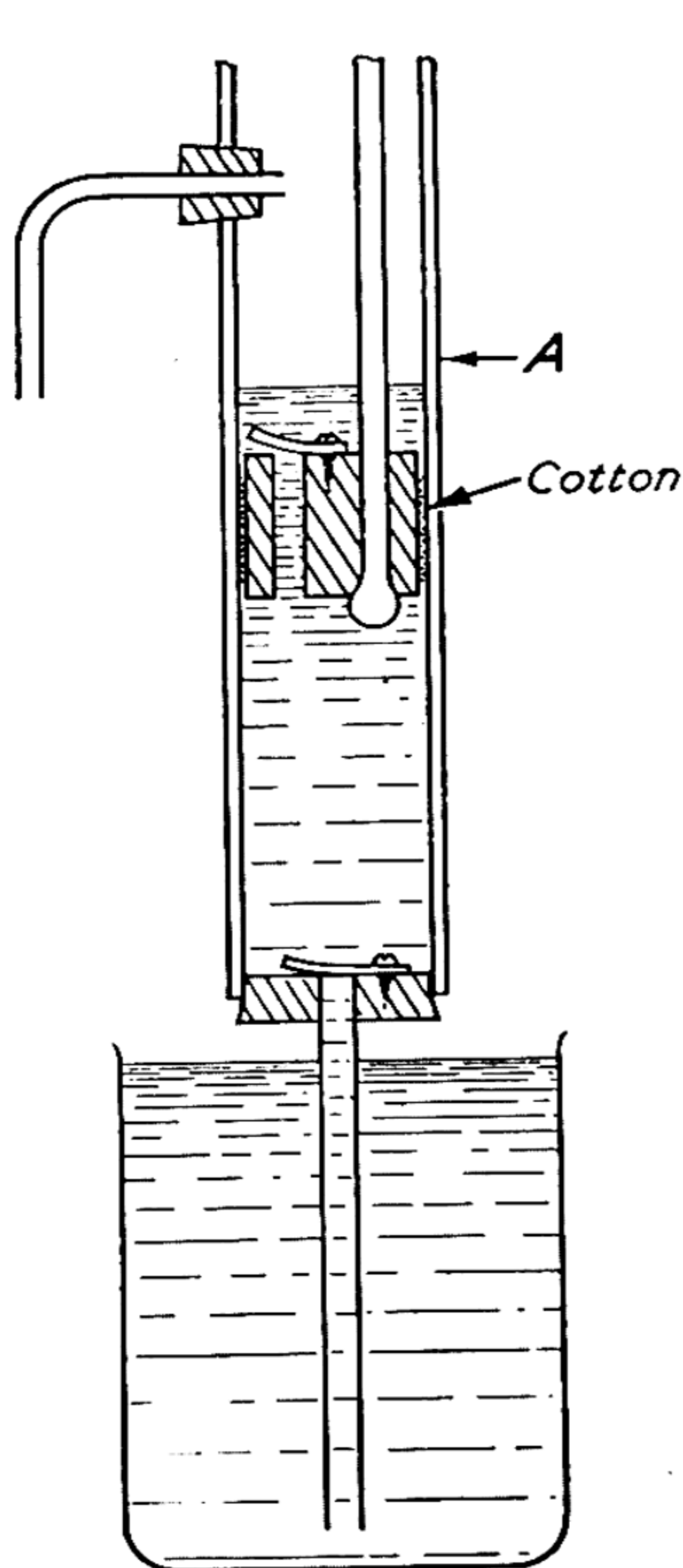


FIG. 21. MODEL SUCTION PUMP

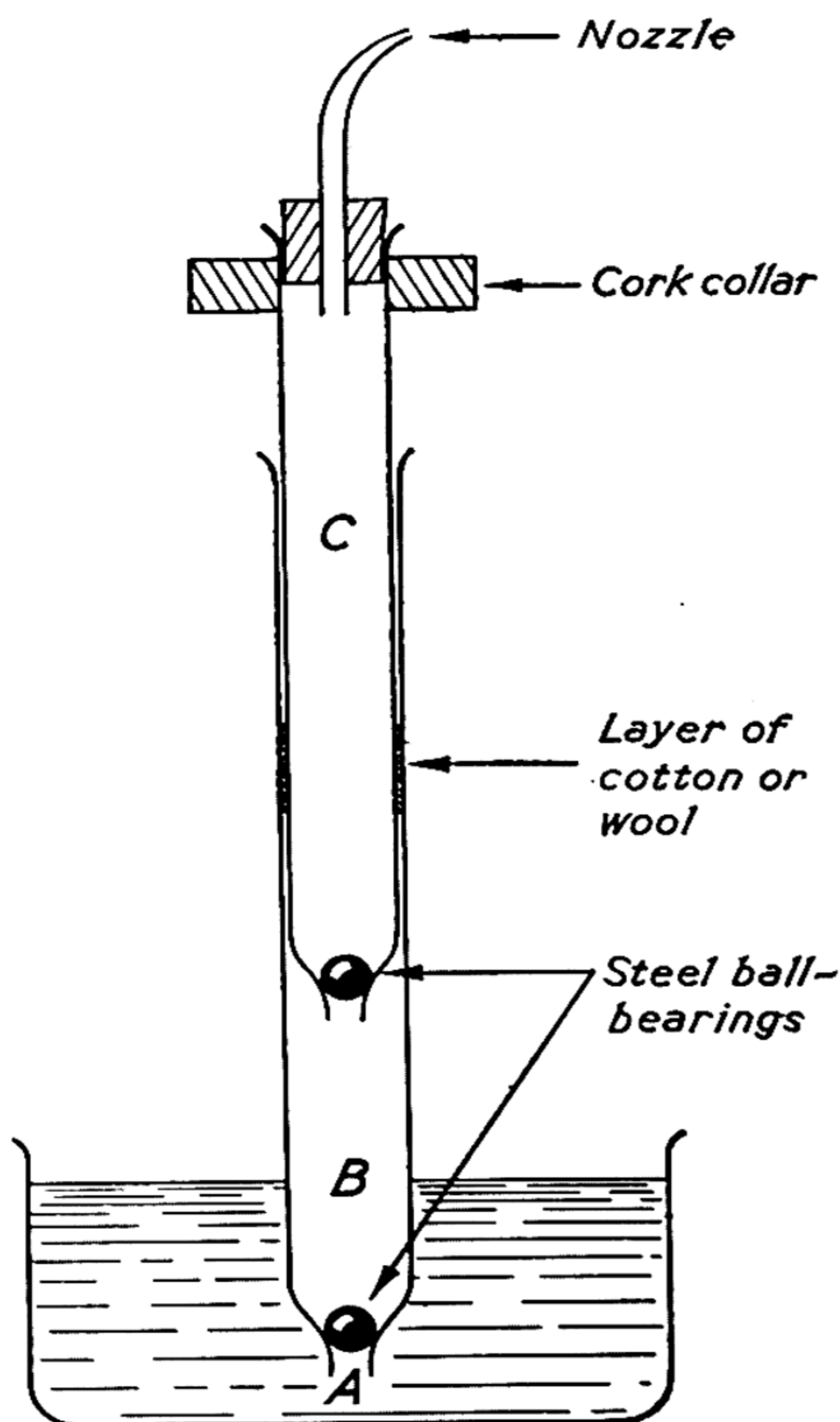


FIG. 22. MODEL INTERMITTENT FORCE PUMP

The knob on the end of the glass rod is made by melting the end in a Bunsen flame. If a cork is used, it may be necessary to wrap it with cotton to get a good fit inside the tube *A*. Water can now be drawn into the barrel of the pump by raising this piston.

If a two-holed stopper is used, as shown in Fig. 21, and a hole made in the side of the tube *A*, as already described under topic *A* (Automatic Siphon), a simple suction pump can be made.

An Intermittent Force Pump

Two strong test-tubes, one of which slides freely inside the other, are required. Holes must be made in the ends of each. The best way of doing this is to use a blowpipe flame as described under Automatic Siphon, and, when the glass becomes plastic, blow with the mouth over the open end.

If the inner tube cannot be made into a watertight piston by merely using grease, a layer of wool or cotton should be wrapped round its lower end. Where the cotton is to be wrapped the surface of the tube should be roughened with a file or emery paper. The cork collar round the upper part of the inner tube prevents the inner tube from being pushed too far down.

The open end *A* is placed below the surface of some water in a dish. The inner tube is pulled upward and water passes into *B*. On the downward stroke of the inner tube, water passes into *C*, and ultimately is forced out at the nozzle on each downward stroke.

Continuous-acting Pump

The pump described in the previous section can be converted into a continuous-acting pump in the way shown in Fig. 23. The flask illustrates how the large iron compression chambers to be seen at the waterworks pumping stations keep the flow of water constant and take some of the strain off the pump.

The inner tube of the pump is fitted with a two-holed cork, and a small flask is fitted as shown.

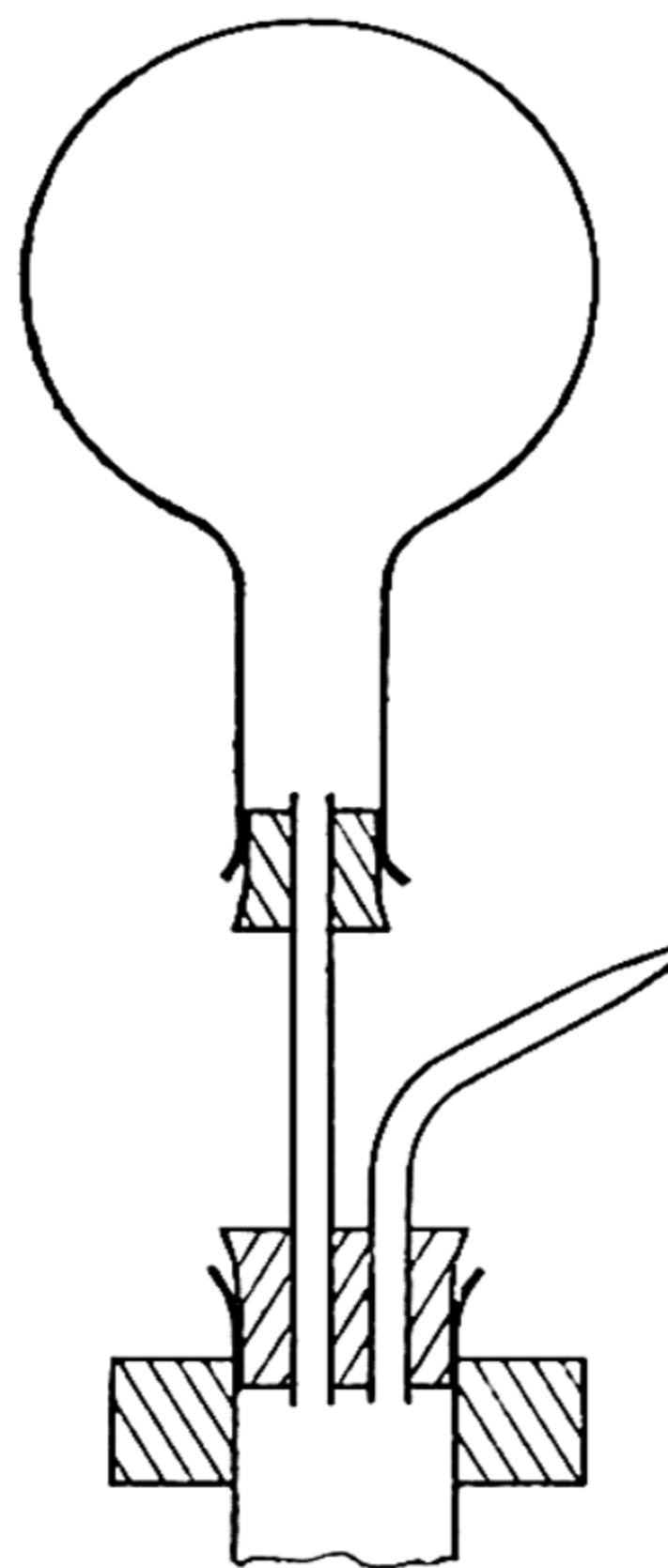


FIG. 23. MODEL
CONTINUOUS-ACTING
FORCE PUMP

To show that Horizontal and Vertical Pressure are the same at Any Point in a Liquid

A simple but very convincing method of demonstrating this is described at p. 46 of *The Science Master's Book*, Series II, Part I.

Hydraulic Rams and Presses

A model hydraulic ram is described in *Simple Scientific Experiments*, by A. de Ratti.

Model hydraulic presses are described in *Hygiene of the Home*, by A. H. Whipple, and in *The Science Master's Book*, Series II, Part

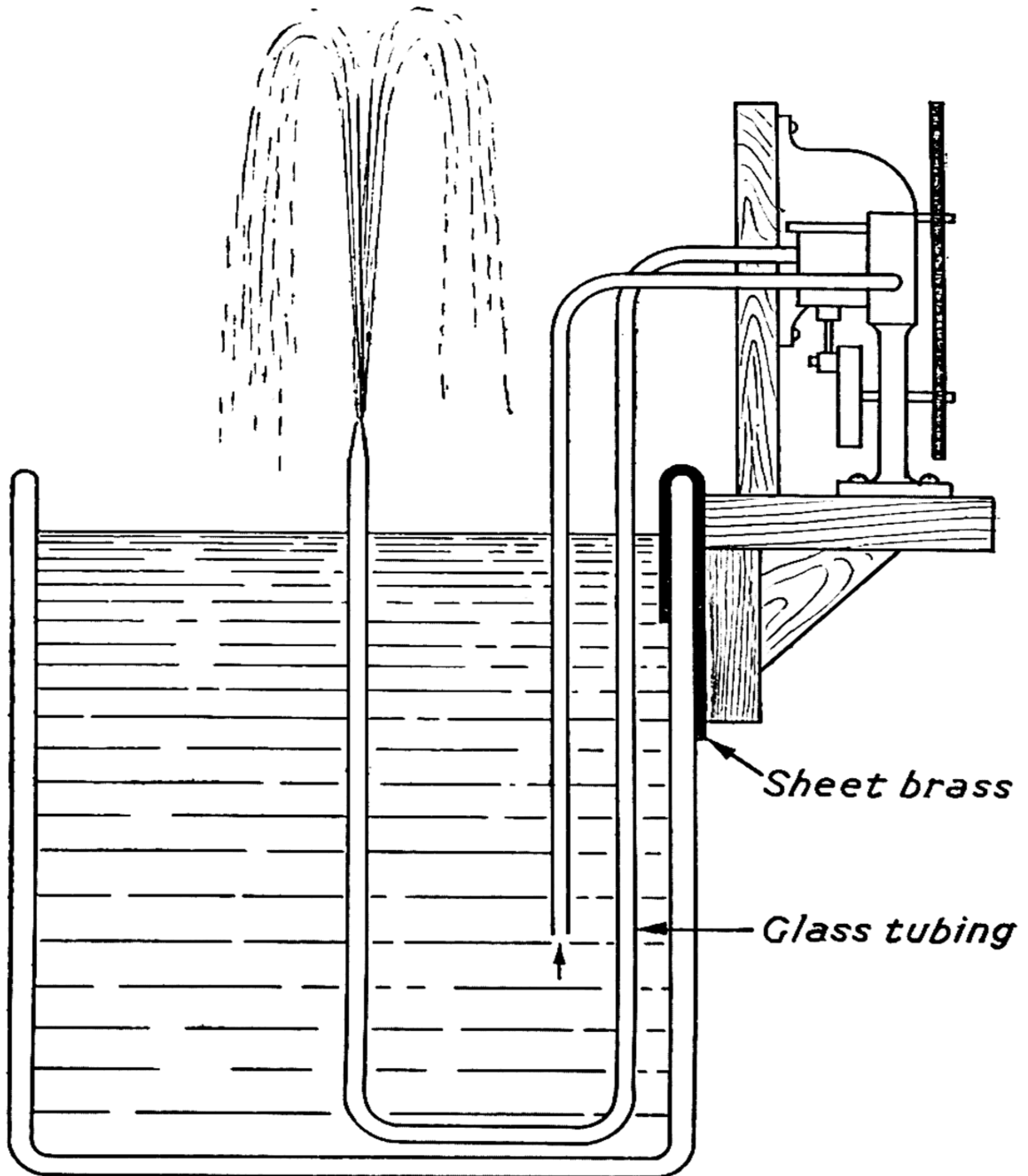


FIG. 24. FOUNTAIN

I, p. 45. The press described in the latter book enables the teacher to raise himself up in front of the class by merely pouring water down a narrow glass tube.

Fountains

A description of a model fountain, a self-filling bucket, and a floating intake of the type sometimes used in reservoirs is given in *Nature's Wondrous Laws*, by A. T. MacDougall.

A fountain which can be used for aerating the water in an aquarium is illustrated. The fountain is worked by an electrically driven pump. Using a small electric motor and a small model steam engine, the pump can be made for a few shillings. It is fixed to a wooden bracket which has a piece of sheet brass screwed to it. This brass can be bent to form a clip to hold the pump to the side of the aquarium.

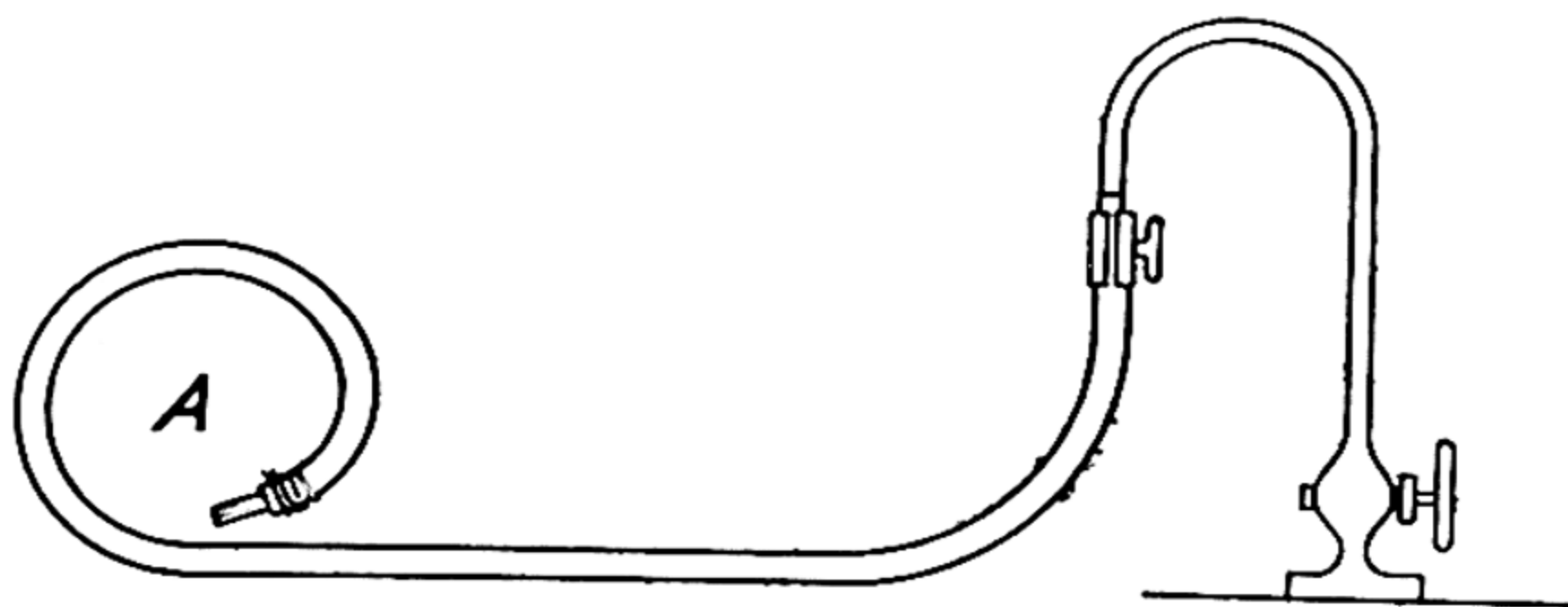


FIG. 25. PRINCIPLE OF THE HEAD-PRESSURE GAUGE

To demonstrate the Principle of the Head-pressure Gauge

A method of making a simple model Bourdon Gauge for pressures of 0–30 cm. of water is described in *The Science Master's Book*, Series II, Part I.

A method of showing the principle of such gauges is illustrated in Fig. 25.

One end of a length of about four or five feet of rubber pressure tubing is connected to a water-tap and fixed firmly by means of a clip. The other end is closed by means of a short piece of glass rod which is held firmly in the tubing by wrapping the end with a few turns of wire.

The end *A* is laid on the table and made into the form of a circle. When the tap is gently turned on the tube gradually straightens out.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

ADLAM, G. H. J. (Editor): *The Science Master's Book*, Series II, Part I.

ALLCOTT, A.: *Pumps*.

ANNISS, F.: *The New Practical Physics*, Books I and II.

BEAN, H. E.: *Everyday Science*, Books II and III.

HOLWAY, H.: *The Story of Water Supply.*

LAUWERYS, J., AND GLOVER, A.H.T.: *The Thirst of Cities.*

LITTLE, W. B.: *Science in the City.*

LITTLE, W. B.: *Science in the Country.*

LITTLE, W. B.: *Science in the Home.*

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School, Books I and II.*

LYNDE, C. J.: *Home Water Works.*

MACDOUGALL, A. T.: *Nature's Wondrous Laws.*

MACDOUGALL, A. T.: *The Marvels of Chemistry.*

RAY, C. (Editor): *The Boy's Book of Popular Science.*

SCARR, W. A.: *Science in Common Things, Book I.*

SPEAKMAN, C.: *Handwork Science.*

TAYLOR, F. S.: *The World of Science.*

THOMPSON, J. M.: *Water Wonders Every Child should know.*

WHIPPLE, A. H.: *Hygiene of the Home.*

See also pp. 46-58 of *Everyday Science Topics, Book I.*

Films

Archimedean Screw (16 mm., silent, 1 reel) (British Instructional Films, Ltd).

Hydro-electric Power (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Purifying Water (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Stresses the need for purifying water, and shows the methods of aerating, filtering, disinfecting, and testing a town's water-supply.)

Water-power (16 mm., sound and silent, 1 reel) (Wallace Heaton, Ltd).

(Shows the energy of rushing water transformed into electrical power, the turbine in action, and how the resultant power is employed.)

Water-power (16 mm., sound and silent, 1 reel) (G.B. Equipments, Ltd).

(Illustrates modern methods of utilizing water-power to generate electricity. A typical power scheme in the Grampians is taken as an example and is used to show the damming of a loch, the generating station, and the distribution of the current. Animated diagrams explain the relation of the different parts of the scheme, the importance of the head of water, and the working of a hydraulic turbine.)

Water Purification (16 mm., sound, 3 reels) (Army Kinema Corporation).

Water-supply of New York (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Gives an insight into a typical sanitary water system of a large city. Scenes and animations picture methods used in bringing water from the Catskills through the mountains, under the Hudson river, to New York City.)

Water Service (16 mm., sound, 1 reel) (Central Film Library).

Water Wheels (16 mm., silent, 1 reel) (Educational and General Services, Ltd).

(An elementary film showing a primitive method of using water-power.)

White Fuel—Hydro-electric Power (16 mm., silent, 1 reel) (Central Film Library).

(Winnipeg river and tributaries, the falls, the generating station, the grid to Winnipeg, and the receiving station.)

The Filter (16 mm., silent, 1 reel) (G.B. Equipments, Ltd).

The Suction Pump (16 mm., silent, 1 reel) (Cinepro, Ltd).

Film-strips

London's Water-supply (Visual Information Service).

Science in Everyday Life—Water (Army Kinema Corporation).

Tennessee Valley Authority (Common Ground, Ltd).

The Development of Power, Wind, and Water (Daily Mail School Aid Dept).

Water for a Thirsty Land (British Instructional Films, Ltd).

Water-supply (British Instructional Films, Ltd).

Water-supply Industry (Historical) (Common Ground, Ltd).

Water-supply Industry (Modern) (Common Ground, Ltd).

Miscellaneous

There are a number of photographs and lantern-slides on "Pumping Machinery and Water-supply" obtainable from the Science Museum, South Kensington. Full particulars of all teaching aids obtainable from the Science Museum will be provided on application to the Director.

(D) Respiration

Pupils must have some knowledge of the composition of the air and the properties of oxygen, nitrogen, and carbon dioxide before work on this topic can proceed.

The following introductory experiments will be found helpful:

- (1) Preparation and properties of oxygen.
- (2) Preparation and properties of carbon dioxide.
- (3) Air is necessary for rusting and combustion.
- (4) Which part of the air is used during combustion and rusting.

Three of these experiments are referred to in *Everyday Science Topics*, Book I; details of the other are given below.

Oxygen can be obtained directly from the air by heating litharge (PbO) gently for several hours in a porcelain dish. Red lead (Pb_3O_4) is obtained, and when this is heated strongly in a hard glass tube enough oxygen can be recovered to relight a glowing splint.

Since a demonstration that air is necessary for respiration must lead to the death of the plant or animal experimented upon, experiments must be carried out only with plants and the lower animals.

Methods of demonstrating that an adequate supply of air is essential for combustion are described in *Everyday Science Topics*, Book I, p. 84.

Air is necessary for the Rusting of Iron

An excellent way of proving that air is necessary for the rusting of iron is illustrated in Fig. 26. *A* is a barometer tube. A little water, which has been previously boiled to expel all air, is introduced into the space above the mercury by using a pipette, the end of which has been drawn out and bent as illustrated. A short piece of iron

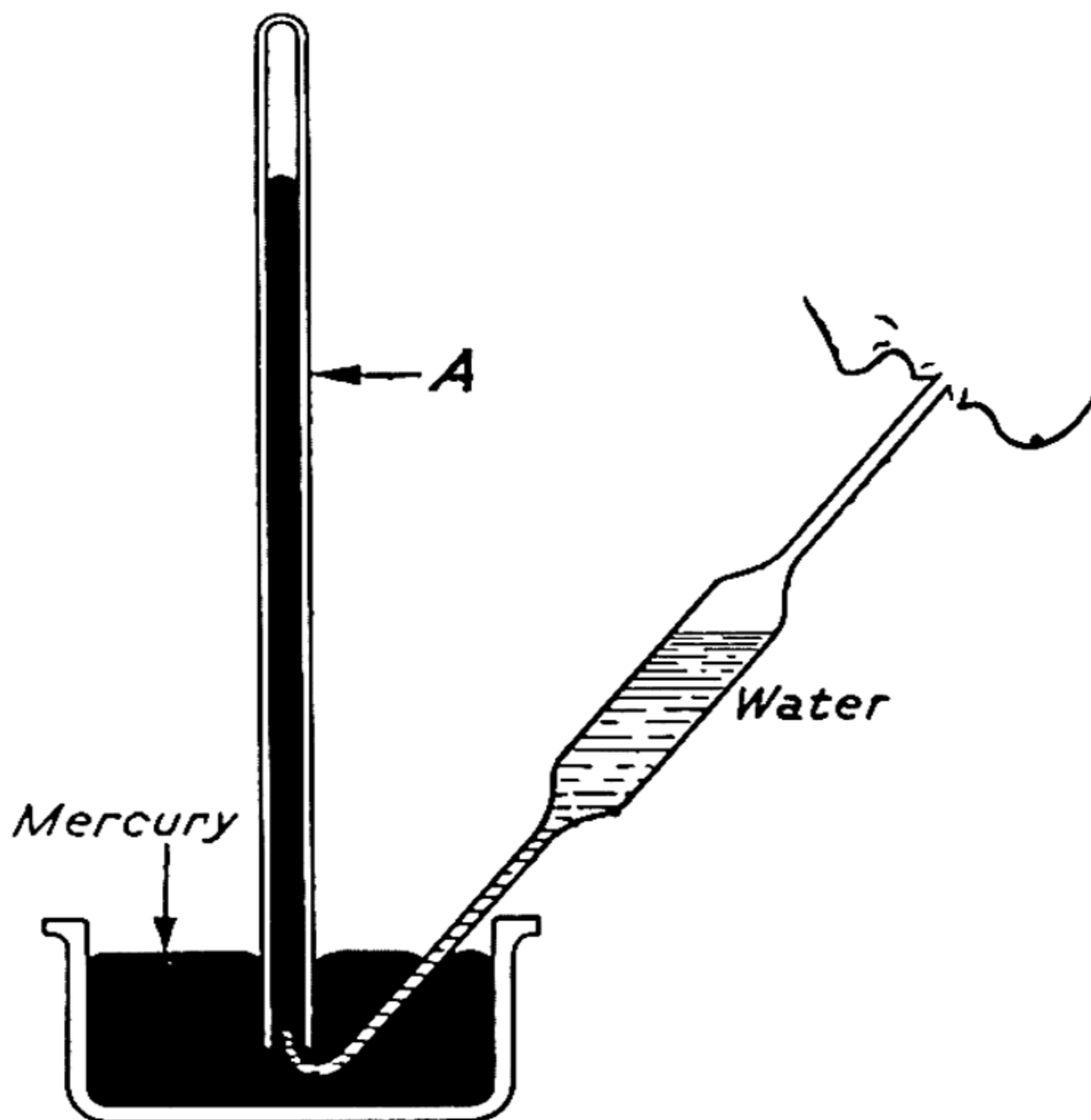


FIG. 26. APPARATUS TO SHOW THAT AIR IS NECESSARY FOR RUSTING IRON

rod which has been polished by rubbing with a smooth file is then placed in the open end of *A* while it is under the mercury. The iron moves up into the space above the mercury. A similar piece of iron is placed in a tube containing air and water vapour. After a few days the two pieces of iron may be compared. The iron above the mercury in the barometer tube will not rust, while the other piece will be covered with rust.

Which Part of the Air is used during the Rusting of Iron?

A method of showing which part of the air is used during the rusting of iron is illustrated in Fig. 27. The water rises in the lamp-glass, and approximately one-fifth of the air is used up. The remainder of the air may be tested to show lack of oxygen, and the increase in weight of the iron filings may be measured.

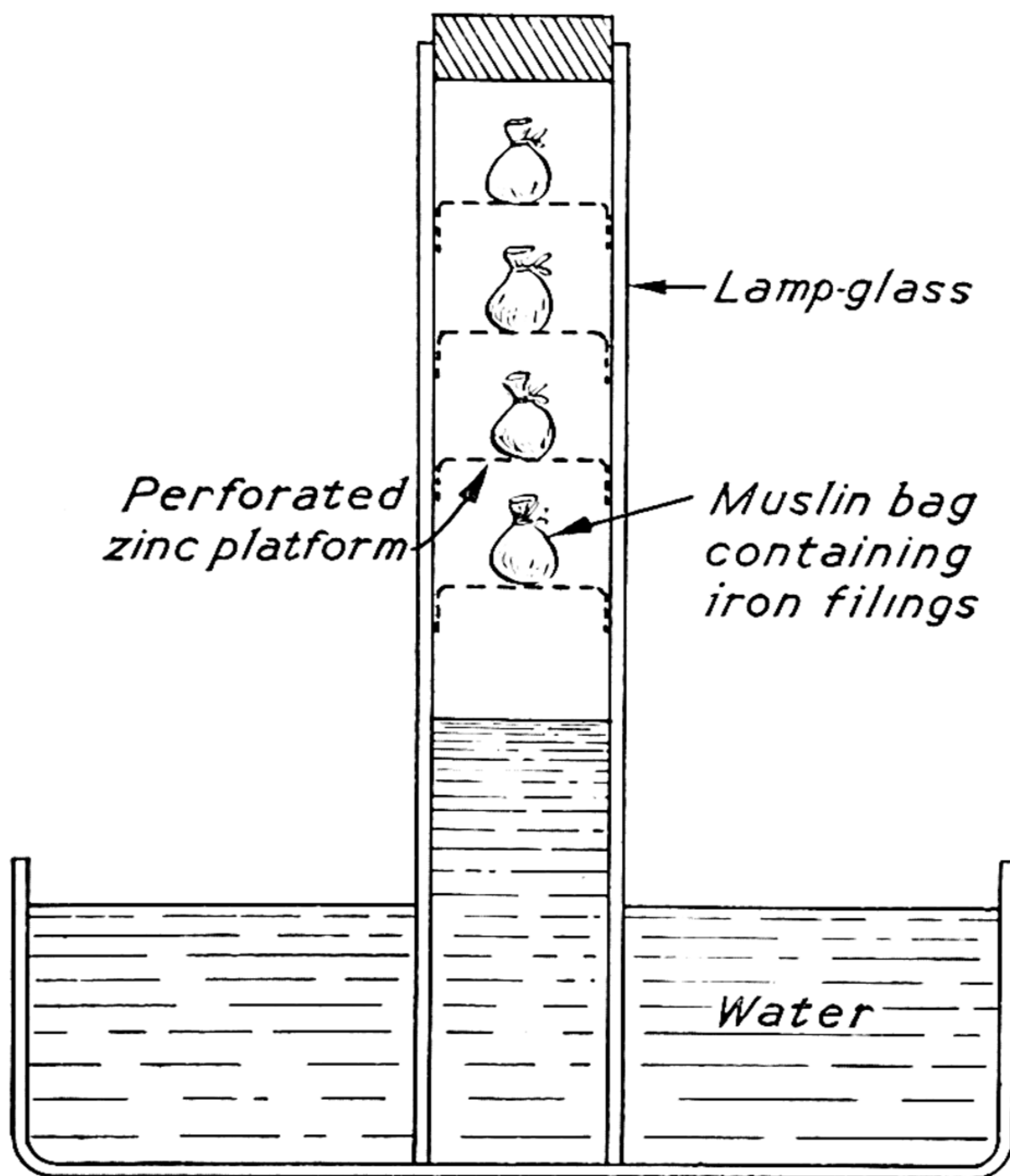


FIG. 27. TO SHOW HOW OXYGEN IS ABSORBED DURING RUSTING OF IRON

To show that a Plant requires Oxygen

The oxygen in the air under the first bell-jar is absorbed by the solution of pyrogallol in caustic potash, and the plant dies. The plant under the second bell-jar breathes in oxygen and breathes out carbon dioxide. The carbon dioxide is assimilated by the plant and oxygen given out. The plant under the second bell-jar will thus live

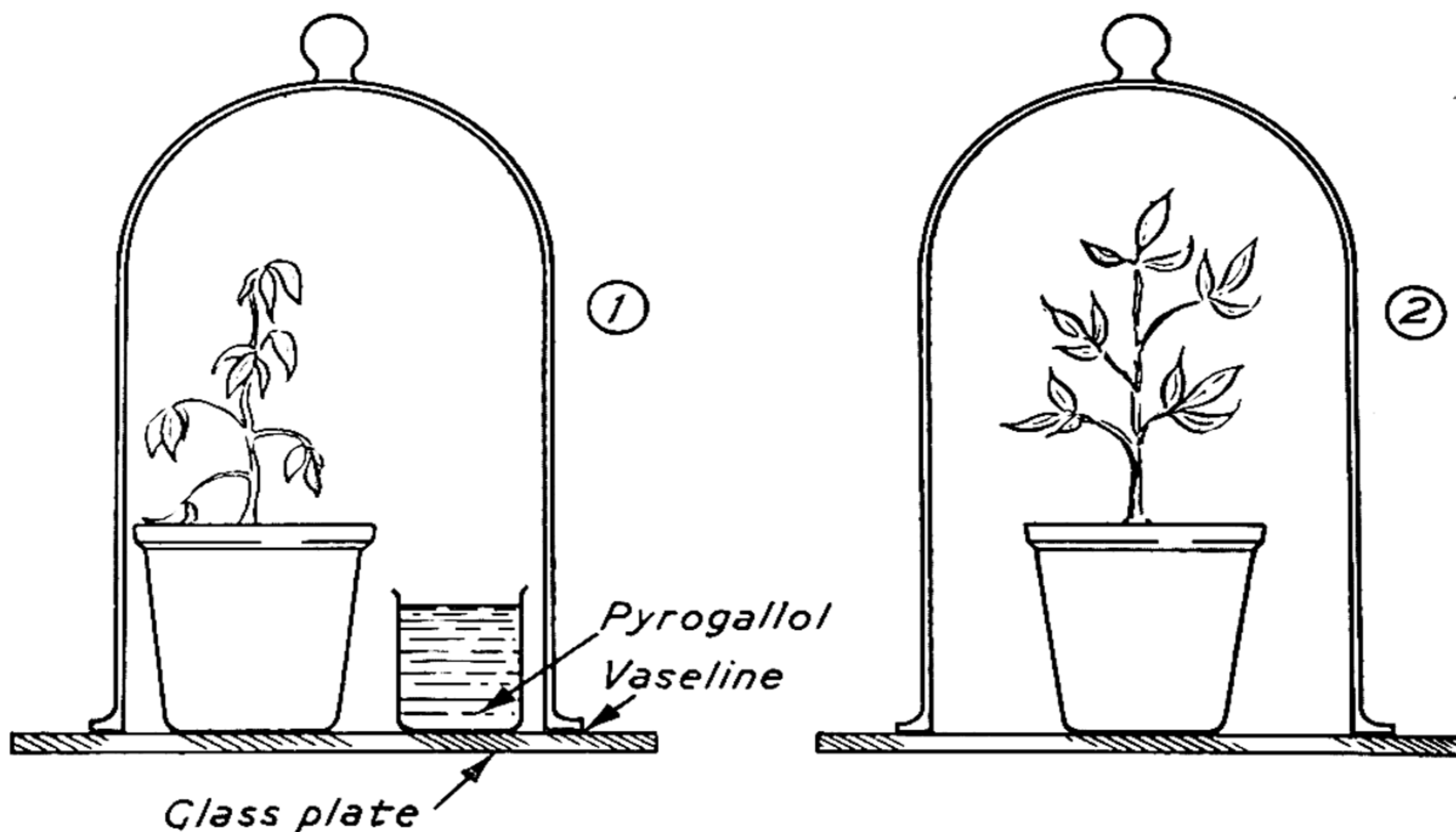


FIG. 28. TO SHOW THAT A PLANT REQUIRES OXYGEN

and grow. Both plants should be well watered, and placed in a well-lighted position. Fuchsia plants are ideal for these experiments.

To show that Oxygen is necessary for Respiration

TO SHOW THAT SEEDS CAN RESPIRE FOR A TIME BY USING THE OXYGEN FROM THEIR TISSUES

Take three U-tubes and three narrow jars.

Place five or six soaked peas in one arm of each tube, insert a cork with a piece of damp cotton-wool fastened to it, and invert the U-tube with one arm in the narrow jar.

Jar 1—Half fill with water.

Jar 2—Half fill with strong caustic-potash solution.

Jar 3—Half fill with strong solution of pyrogallol in caustic potash.

Leave all the jars for a day or two.

RESULT

- Jar 3. The solution soon rises in the arm of the U-tube. The seeds germinate very little. (Pyrogallol absorbs the oxygen from the air in the U-tube. The seeds use the oxygen from their own tissues for respiration, and this is soon exhausted.)
- Jar 2. The solution rises more slowly and to the same extent. The seeds germinate well. (The caustic-potash solution absorbs the carbon dioxide from the air in the U-tube and also that which the seeds give out when they respire. The seeds use the oxygen from the air in the tube for respiration, and so the caustic-potash solution rises slowly in the U-tube for about one-fifth of its length.)
- Jar 1. The water rises very little, but the seeds germinate well. (The seeds use oxygen from the air in the U-tube for respiration.)

*To examine Protococcus with
Microscope or Micro-projector*

Scrape *Protococcus* from the bark of a tree and place a very small amount in a drop of water on a microscope slide.

Break up these small powdery plants in order to see more clearly the single cells.

Lower over the specimen a cover-slip supported by a needle at one side, then carefully slip out the needle to exclude air-bubbles. The needle may be purchased from a dealer or it may be prepared easily by fixing a sewing-needle in the handle of a worn-out camel-hair brush or penholder.

To examine Spirogyra

Mount a few threads of *Spirogyra* in a drop of water on a microscope slide, place a cover-slip over, and examine with microscope.

To stain the cell contents, and to find the nucleus, place a few drops of iodine solution on the slide at one edge of the cover-slip, taking care that none of the iodine flows on top of the cover-slip.

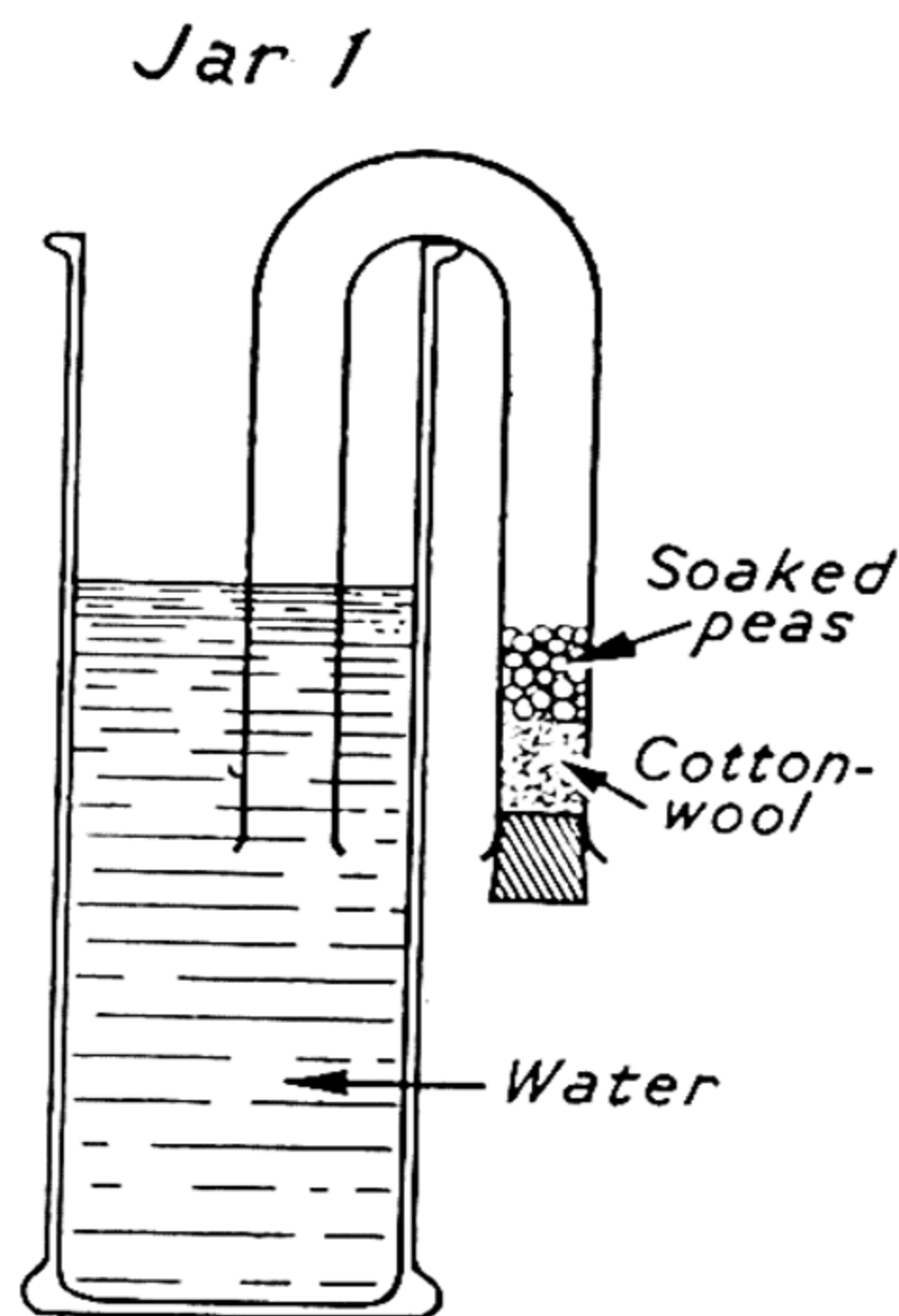


FIG. 29. APPARATUS TO SHOW
THE NECESSITY OF OXYGEN FOR
RESPIRATION

Hold a small piece of blotting-paper at the opposite side of the cover-slip to soak up some of the water and to cause the iodine to flow under the cover-slip and take its place.

Respiration in Yeast Plants

Baker's yeast consists of a mass of small oval cells, each of which is a whole plant.

Place a little yeast and 10 per cent. sugar solution in a flask, fit with a one-hole rubber bung, and connect by means of glass tubing

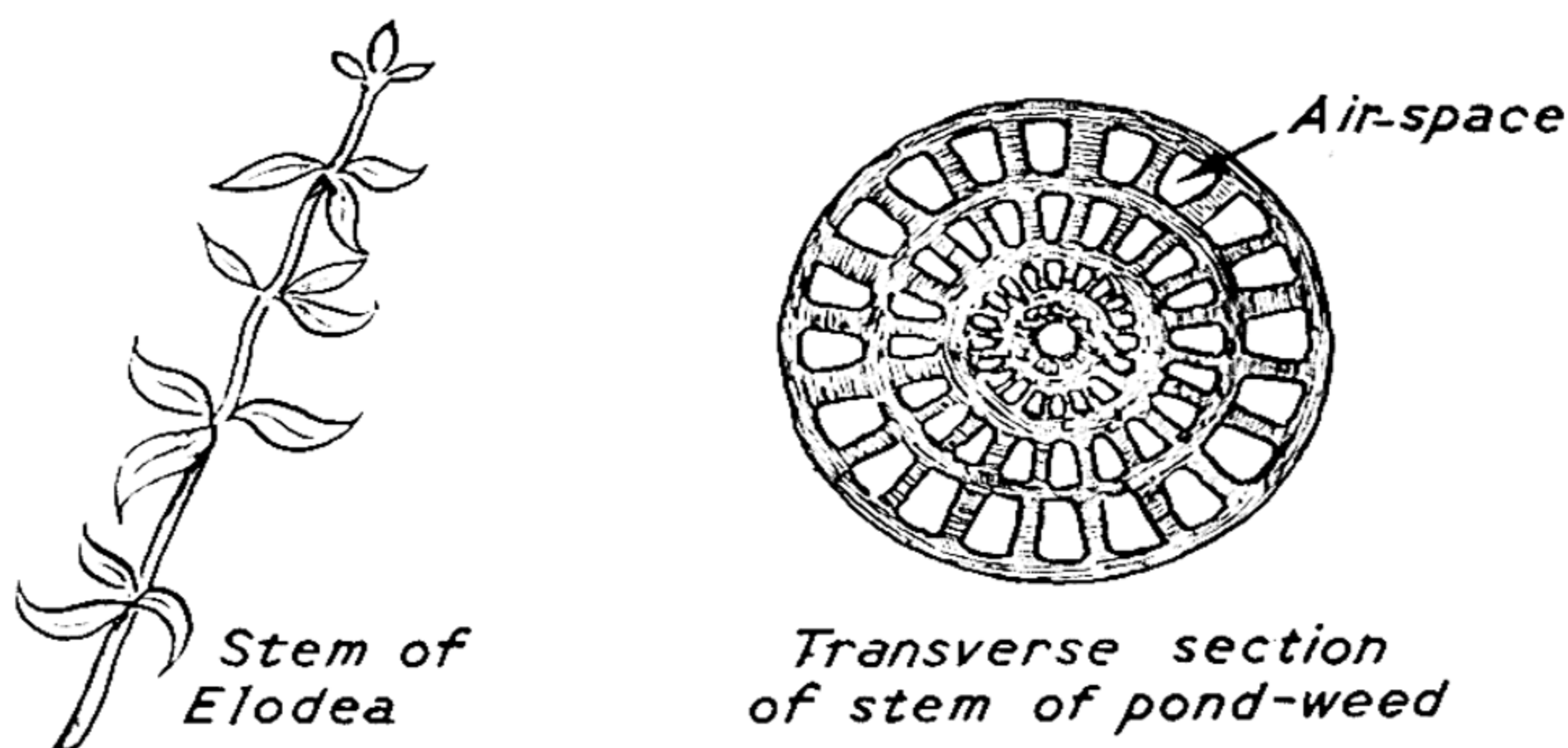


FIG. 30. EXAMINING A SECTION OF WATER-WEED

to a small beaker containing lime water, allowing the free end of the tube to dip into the lime water.

Stand in a warm place. The lime water becomes cloudy as carbon dioxide is given off by the yeast plants.

Take some of the liquid from the flask by means of a dipping-tube, mount a little on a microscope slide, place a cover-slip over, and examine microscopically. Look for the yeast cells, some of which will be 'budding,' or growing new cells.

Note. A dipping-tube may be purchased, or easily made by heating in a flame the centre of a piece of narrow glass tubing, drawing it out, breaking it evenly in the centre with a file when cool, and smoothing the cut edges by heating in the flame. To use, place a finger over the wide end, plunge the other end in the liquid, and remove the finger, when the liquid will rise in the tube. Replace the finger and remove the tube together with contents.

Respiration in Water Plants

(a) Examine Elodea (Canadian pond-weed) or any other completely submerged water plant. Plants which live completely submerged absorb oxygen dissolved in the water in which they live.

Notice that the stems, leaves, and roots have very thin skins to allow water to soak through easily. Take them out of the water and they soon shrivel.

Take a fresh plant and remove a leaf from the end of one of the stalks, mount in a drop of water on a microscope slide, and examine with microscope.

(b) Examine a transverse section of the stem of a water plant. To do this cut thin slices across the stem with a wet razor, mount

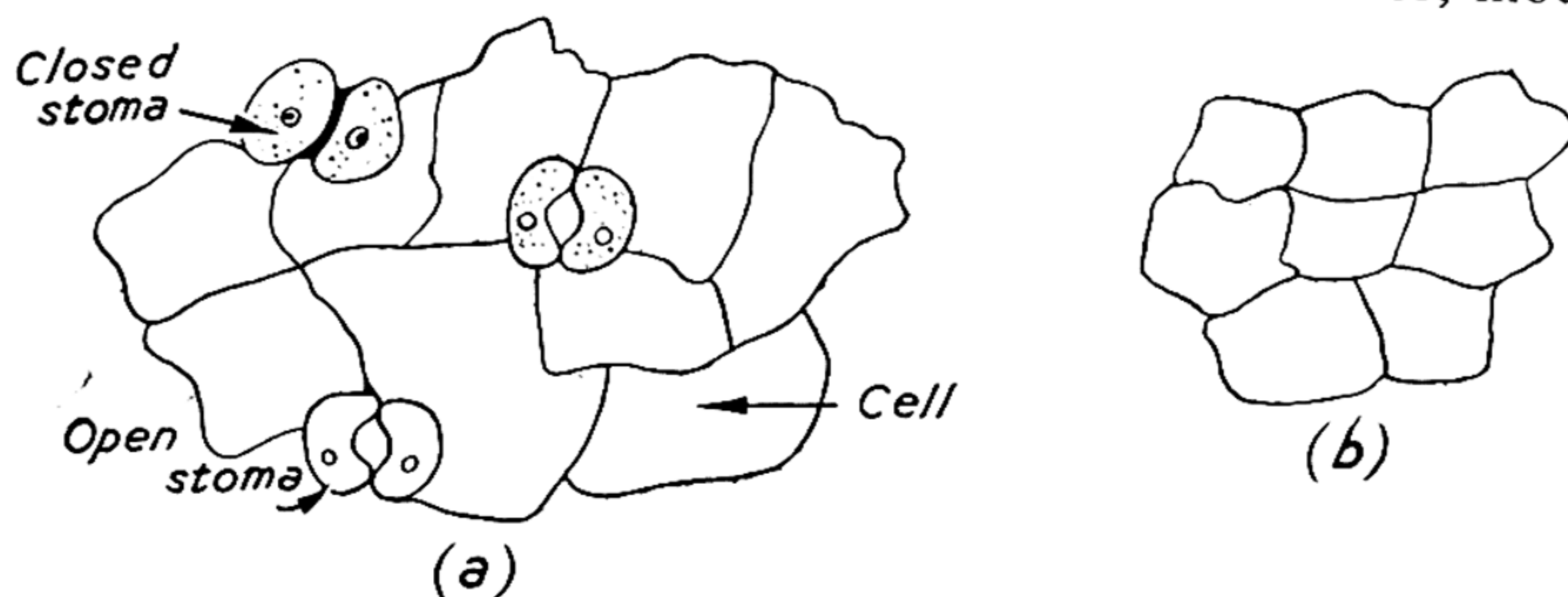


FIG. 31. STOMATES

(a) Under surface, (b) upper surface, of leaf.

the thinnest section in a drop of water on a microscope slide, and examine with microscope. Note the unusually large air-spaces.

Compare with the transverse section of the stem of a land plant—e.g., sunflower.

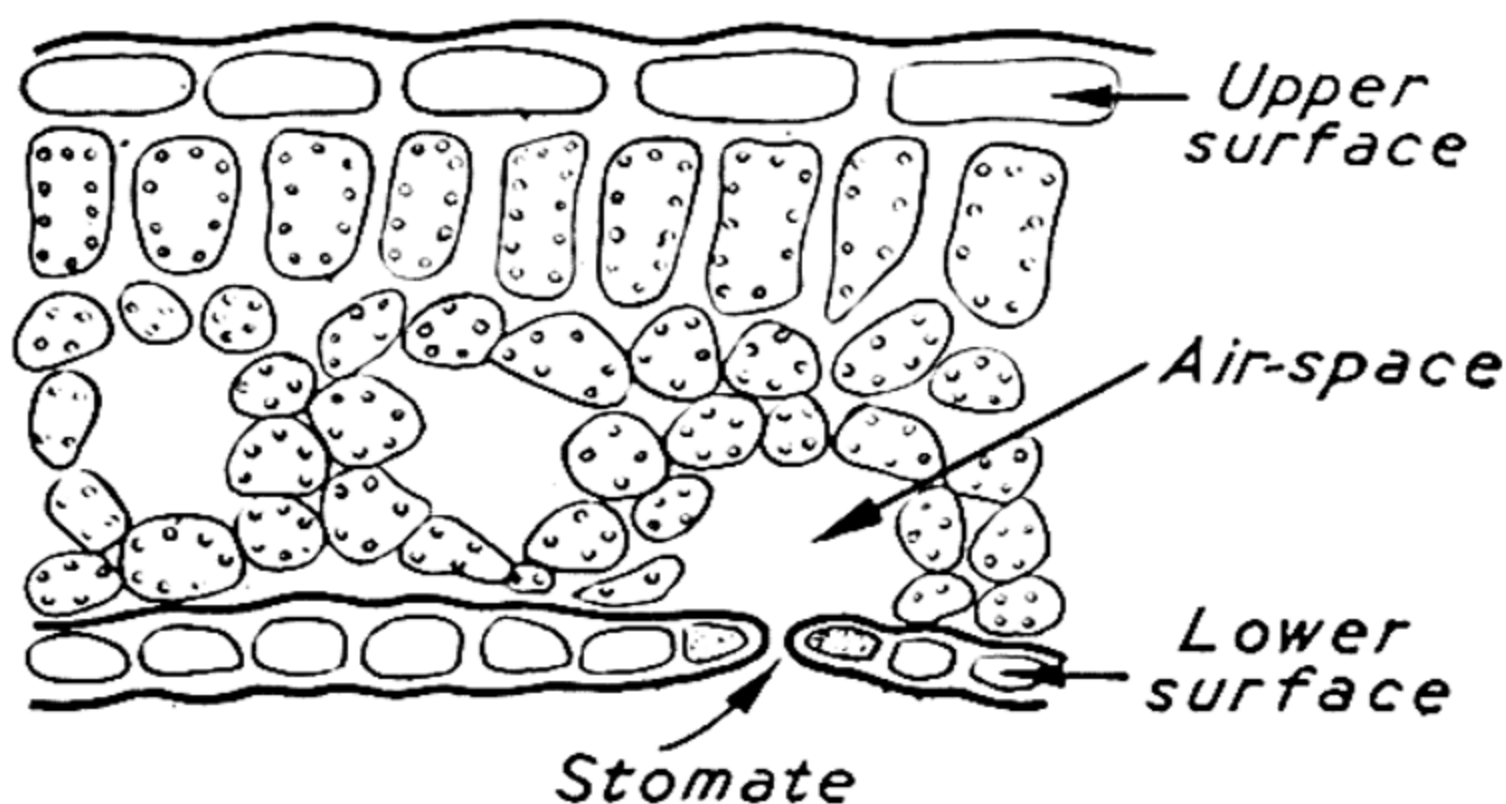


FIG. 32. AIR-SPACES IN A LEAF

To examine Stomates on the Upper and Under Sides of a Leaf

Select a plant from which the epidermal layers peel easily—e.g., lily, hyacinth, or iris.

Scrape off a piece of skin from the upper and under surfaces, mount in a drop of water, and examine with the micro-projector.

There are more stomates on the under side of the leaf. Air enters by means of these pores, and carbon dioxide is given out from them during respiration. Young stems have stomates also.

To examine Air-spaces inside a Leaf

Wedge a flat leaf between two pieces of carrot.

With a wet razor cut thin slices across the carrot and leaf.

Choose the thinnest section of the leaf, mount in a drop of water, and examine with micro-projector.

Note the air-spaces. These communicate with the stomates.

How Animals respire—Methods of Respiration

The pupils should be able to observe, in the laboratory, the methods of respiration in caddis larvæ, the cockroach, crayfish, dragon-fly larva, fish, newt, frog, pond-snails, water-beetles, and the gnat. All these creatures should be kept in small aquaria, and each aquarium should have a label giving the names and coloured pictures of the inmates. Cigarette-cards and the British Museum (Natural History) coloured postcards are excellent for helping pupils to identify the various creatures kept in the aquaria.

It is much better to have a considerable number of small aquaria than one or two large ones. Suitable glass tanks can often be obtained locally for a few shillings from garages or electrical contractors. Messrs A. W. Gamage, Ltd, Holborn, London, E.C.1, are sometimes able to supply glass tanks suitable for aquaria.

A method of making wooden tanks with plate-glass fronts is described in *The Laboratory Workshop*, by Duckworth and Harries. If these are carefully made they give excellent service. Some very helpful information on aquaria and their management is to be found in *Life in Ponds and Streams*, by W. S. Furneaux. The *Descriptive*

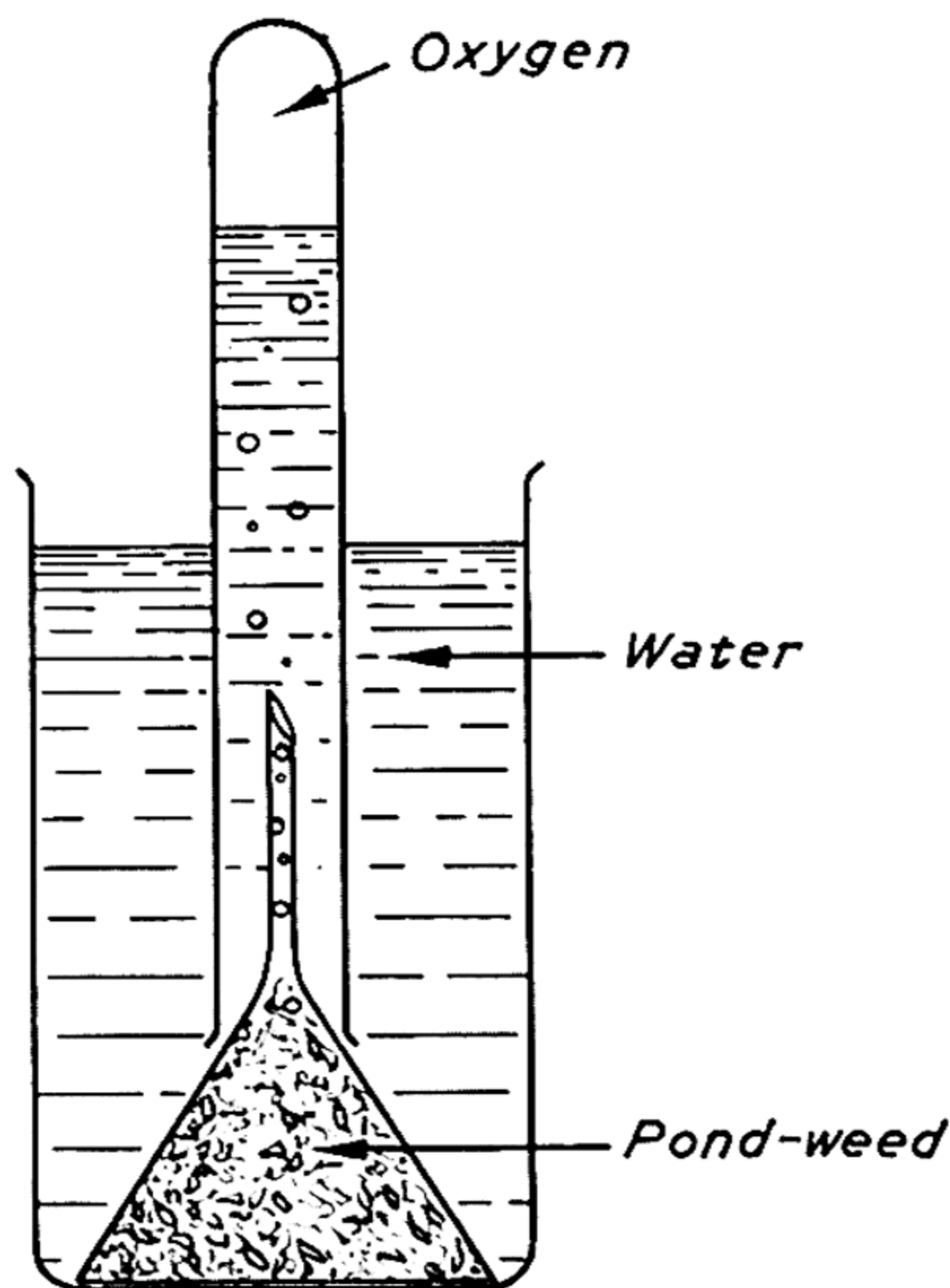
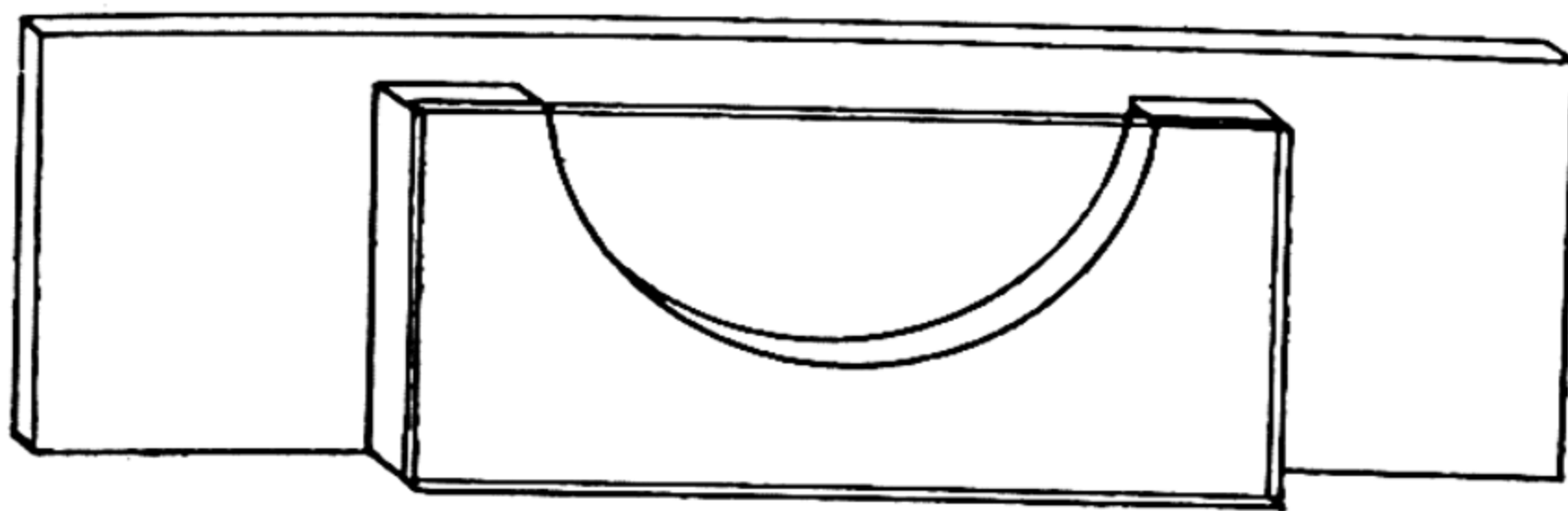


FIG. 33. TO DEMONSTRATE HOW WATER PLANTS GIVE OUT OXYGEN

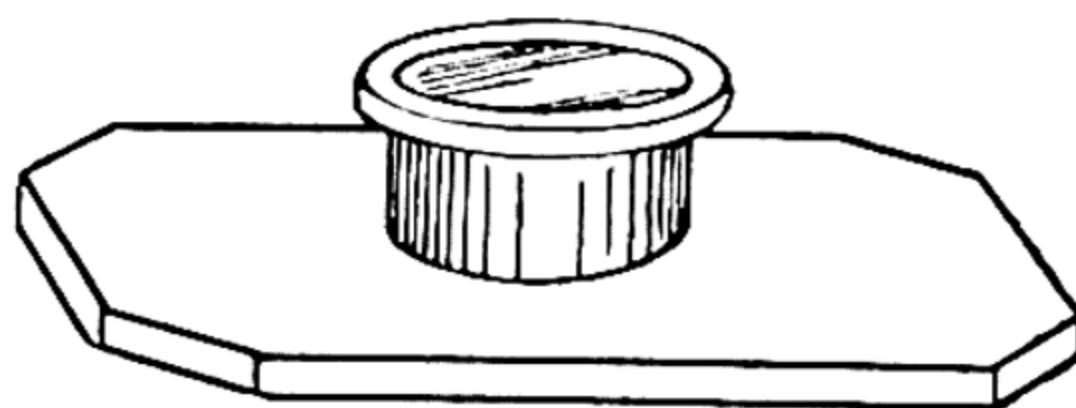
Guide to the Garden Pool and Catalogue of Creatures for Indoor Aquaria, issued by L. Haig, of Beam Brook, Newdigate, Surrey, contains much valuable information. Where the creatures mentioned above cannot be obtained locally they may be purchased from Mr Haig.

How Oxygen is given out by Water Plants in Aquaria

To show that, in sunlight, plants in aquaria absorb carbon dioxide and give out oxygen necessary for respiration the apparatus



Animalcule trough



Live box

FIG. 34. ANIMALCULE TROUGH (*above*) AND LIVE BOX (*below*)

illustrated in Fig. 33 may be used. The oxygen thus liberated by plants in aquaria is partly absorbed by the water. If a little pond-water is warmed gently bubbles of oxygen driven out of solution cling to the sides of the vessel.

Respiration in Water Insects

DRAGONFLY

Place living dragonfly larvæ in a watch-glass.

Drop a little powdered carmine into the water near the anus and notice the currents of water into and out of the rectum.

Note. To rear dragonfly larvæ feed on small worms, insects with soft bodies, or frog tadpoles.

FRESH-WATER SHRIMP

Examine a fresh-water shrimp by means of the micro-projector. Use a live box or trough for animalcules to keep the fresh-water shrimp from moving. Both of these accessories can be used in a vertical position without the spilling of the contents, and so are suitable for use with the micro-projector. The live box has a cell attached with a glass top and base, and the top is removable.

Place the specimen in the box together with a little water and gently screw the glass lid down until the specimen is held securely between the two glasses. If carefully handled the creature will not be destroyed. If the animalcule trough is used, place the specimen in it along with a little water.

Observe the heart movements and the movements of the abdominal legs.

Note. To rear fresh-water shrimps place in some of the water in which they were found and add dead leaves, preferably elm.

CRAYFISH

Place a crayfish in water in a shallow dish, preferably white enamel, and by means of a pipette run a little carmine and water mixture below the thorax between the second and third walking-legs. The particles will reappear in front of the head as a result of the current of water passing over the gills and out.

Place one crayfish in cold boiled water from which the oxygen has been driven out by boiling, and another in unboiled water containing dissolved oxygen, and compare the rate of the respiratory movements.

Do not prolong the experiment to the discomfiture of the crayfish.

Note. If crayfish are to be kept for any length of time they should be placed in running water containing plenty of water plants and fed on worms and pieces of raw meat.

How to keep Frogs and Newts

For observations on the methods of respiration in frogs and newts, the special amphibian house illustrated in Fig. 35 may be constructed.

It consists of a wooden box with four legs. It has a sliding glass panel in front and perforated zinc at the back. Holes are bored in the top of the box for ventilation, and these are covered with perforated zinc on the inside. A rectangular piece is cut away from the base of the box so that it fits over the upper edge of a rectangular glass tank. This has a layer of silver sand in the bottom, and water plants, attached to small pebbles, are lowered on to the sand. The

tank is filled with water, and a glass tube leads through the end of the box and into the tank, so that the water may be aerated occasionally. In the bottom of the box to the left is placed a shallow dish, in which several small plants and a little grass are growing. The remainder of the bottom of the box is covered with silver sand and small pebbles. In this way the frogs and newts may live in or out of the water.

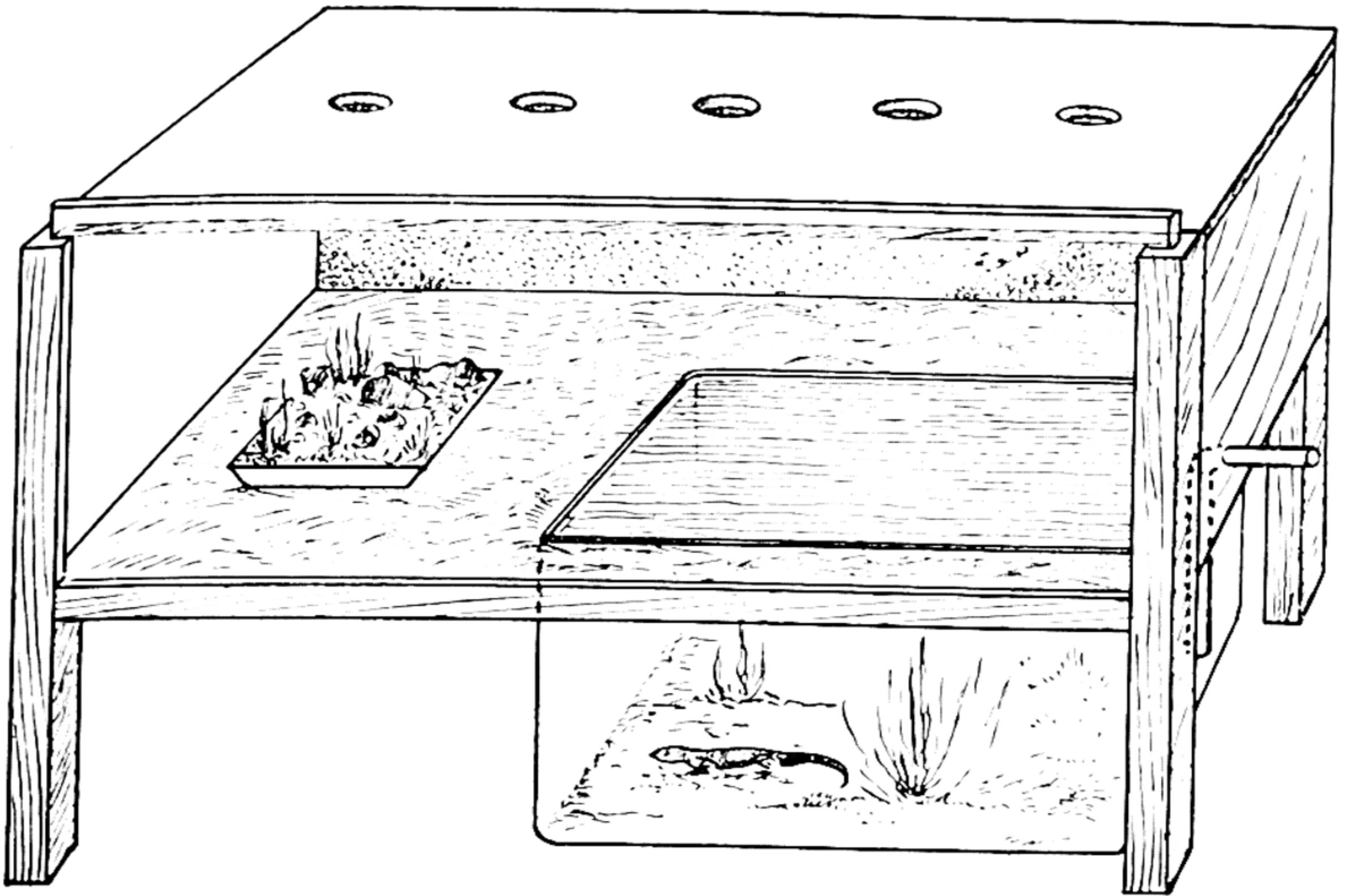


FIG. 35. AMPHIBIAN HOUSE

Examination of a Sheep's Heart

Obtain a sheep's heart from a butcher. (Procure one with fairly long blood-vessels attached.)

Note the four compartments of the heart: left auricle, right auricle, left ventricle, and right ventricle.

Identify the main blood-vessels which enter and leave the heart.

Notice the *thin* walls of the veins which enter the right auricle.

Expose the semilunar valve in the pulmonary artery, which leaves the right ventricle. To do this cut through the pulmonary artery near the heart and look into it. Notice the three flaps of this valve.

In a similar way expose the semilunar valve in the aorta, which carries blood away from the left ventricle. This valve also has three flaps. The use of both these valves is to prevent the backward flow of blood into the ventricles when the heart expands.

Note the *thick* wall of the aorta (artery).

Make sections through the left and right sides of the heart and so expose the valves which allow communication between the auricles and ventricles.

Note the mitral valve with two flaps between left auricles and left ventricles, and the tricuspid valve with three flaps between right auricle and right ventricle.

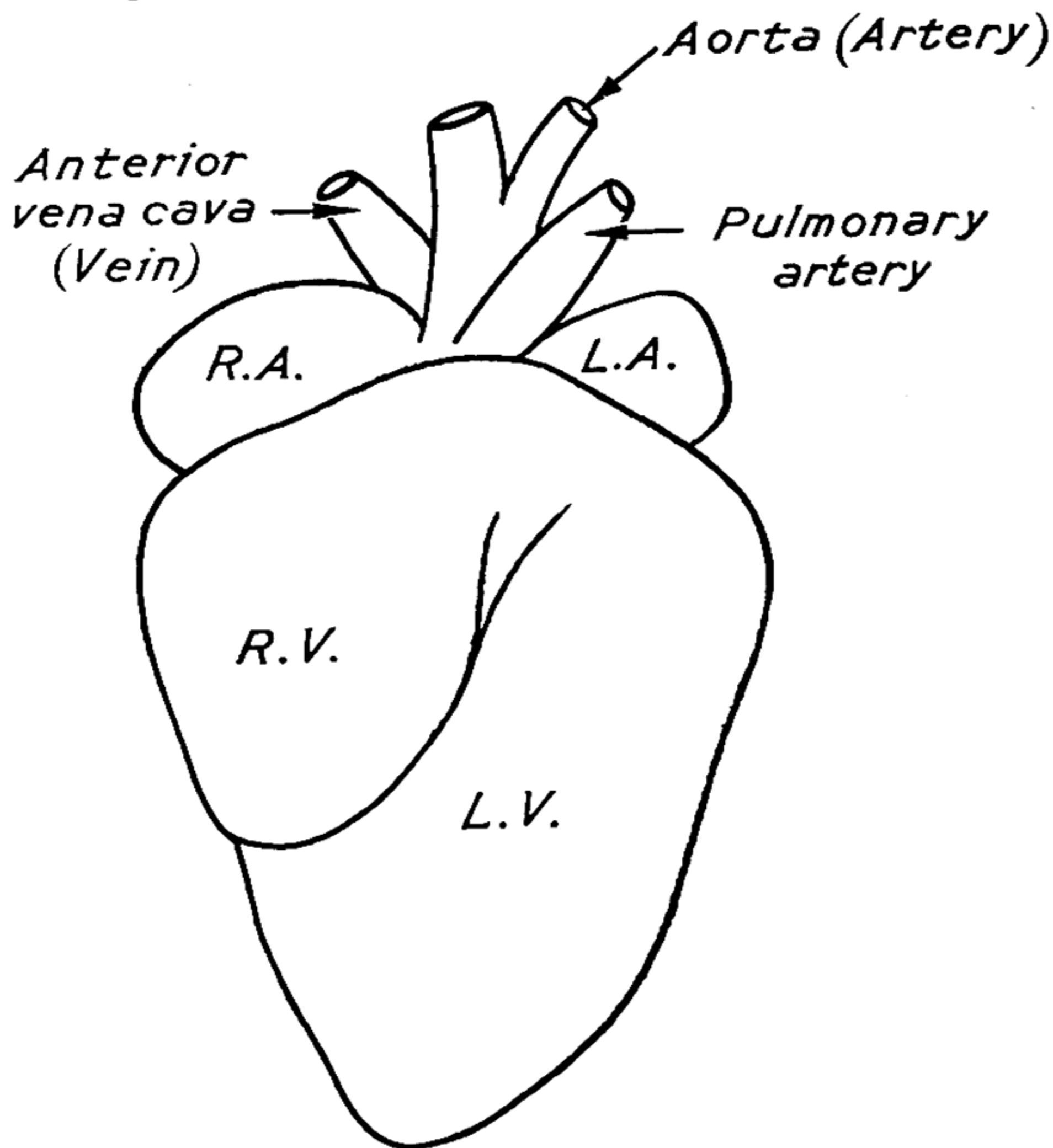


FIG. 36. SHEEP'S HEART

Notice the exceptionally thick wall of the left ventricle, which has to drive blood all over the body. Compare with wall of the right ventricle.

Each pupil should feel his pulse by applying his fingers to the artery in his wrist. He should then take his pulse (1) after resting and (2) after strenuous exercise and compare the rates.

To show the Action of the Heart Valves

Take a fresh sheep's heart with blood-vessels attached.

Insert wide glass tubes into the aorta, the pulmonary artery, and the veins entering the auricles.

Tie firmly with string to prevent them slipping out, then suspend the heart by one of the tubes.

Pour water into the tubes passing into the auricles, squeeze the ventricles slightly, and the water will rise in the tubes fastened to the aorta and pulmonary artery.

Due to the action of the valves, there is no backward flow.

To show how Oxygen is conveyed round the Body

DAPHNIA, A COLD-BLOODED CREATURE

Collect water-fleas from the surface of a pond or purchase some from a dealer.

By means of a dipping-tube remove a specimen and examine in water in an animalcule trough or live box.

Observe the beating of the small heart, which can be seen through the transparent body.

Count the number of beats per minute.

Warm the slide a little and count the number of beats per minute.

The water-flea is a cold-blooded creature, and so the heart beats more quickly (up to a certain limit) with increase of temperature. Notice that there are no blood-vessels at all, and that the blood is colourless and is kept moving by means of the body muscles and the small heart. The blood distributes oxygen round the body.

To culture Daphnia feed weekly by adding thick malted milk-paste consisting of 1 gram of Horlick's Malted Milk to 50 c.c. of water. Alternative method: add a little boiled bone-meal or sheep manure or decaying leaves. The water-fleas feed on the bacteria which develop.

To dissect a Rabbit to show the Interior of the Chest

Obtain from a dealer a freshly killed rabbit.

Fasten it down on its back on to a wooden board; then cut through the skin only along the middle line.

Fasten back the flaps of skin with nails or dissecting-pins after having separated the skin from the underlying tissues.

Cut through the abdominal wall along the middle line and turn back the flesh.

Remove the muscles and expose the ribs.

Cut through the ribs on each side of the breast-bone and remove the latter. Note heart, lungs, and diaphragm.

Trace the arteries and veins between the heart and lungs.

Sever the windpipe, and after attaching to it a bicycle-pump try to inflate the lungs.

Cut through one of the lungs and look for the bronchial tubes.

Allow pupils to use a stethoscope on each other to listen to the sounds made when air enters and leaves the lungs.

Examination of Human Blood

Bend the finger at the end joint, then prick with a sterilized needle at the base of the nail.

Place the drop of blood on a clean microscope-slide and draw it out into a very thin film by dragging one side of a square cover-slip through it.

Cover with a clean cover-slip and examine with the micro-projector. (It is essential that the smear should be as thin as possible and that all the glassware used should be absolutely clean.) Note the red corpuscles, flat and round in shape, which carry oxygen from the lungs to the body cells. The white corpuscles which help to destroy harmful bacteria may also be seen. Notice that there are many more red corpuscles than white.

The Action of the Air in the Lungs on the Blood

This may be demonstrated by obtaining from a butcher some fresh blood. To prevent the blood from clotting it should be mixed with strong salt solution.

A little of the blood should then be placed in a large test-tube, and air from foot bellows should be passed through it. The blood will become bright red.

If it is then left to stand it will become dark purple as it loses its oxygen.

Impurities in the Air

The presence of dust particles in the air of the science room may be shown by passing a beam of light from an optical lantern across the darkened room or by sucking air through a moistened white piece of cloth placed over the inlet tube of a vacuum-cleaner.

To show that light is invisible when passed through perfectly clean air the beam from an optical lantern may be passed through a rectangular glass trough, the sides of which have been smeared with glycerine. The trough should be covered with a piece of glass, sealed to the trough with Vaseline so as to form an airtight chamber.

Some interesting information on air pollution is contained in *The Romance of a Lump of Coal*, a booklet issued by the British Gas Council, and literature of the National Smoke Abatement Society.

Use should be made of the Registrar-General's Reports, which indicate how the length of life of each class of the community is almost directly related to their access to the open air. The effect of dust and soot in the air on plant life may be demonstrated by using two plants of the same type and size, the leaves on one plant being coated with soot.

Reference should be made to the absence of germs in pure, clean air. During Scott's last Antarctic expedition members of the party never suffered from colds, although they experienced extreme cold and discomfort.

Ventilation

The various methods of natural and artificial ventilation may be demonstrated by using wooden boxes with glass fronts as model rooms. The movement of air can be shown by using smoke from smouldering brown paper, and holes in various parts of the boxes serve as windows and doors.

Where the school is situated near a modern cinema the pupils may be taken to see how air is washed, pushed, and drawn into a building by means of electric fans, and warmed if necessary.

The Nature of Sunlight

Valuable information on the production of a really satisfactory spectrum is to be found in *The Teaching of 'Colour' in Elementary Courses of Science*, by Sir E. G. Savage.

Experiments with plants to show the effect of sunlight are described in the books mentioned in the appendix to this topic.

Helpful information on the effects of sunlight is to be found in the journal *Sunlight*, issued by the Sunlight League, 12 Park Crescent, Portland Place, London, W.1. Further information is contained in the pamphlet *Sunlight Treatment at Leysin*, by Dr S. Rollier, and *Sunlight and Health*, by C. W. Saleeby. A pamphlet, *How to Sunbathe*, by Dr Saleeby, can be obtained from the Sunlight League.



FIG. 37. TO SHOW THE EFFECTIVENESS OF VITA GLASS

Samples of glass which transmit the ultra-violet rays of sunlight may be obtained from Messrs Pilkington Brothers, Ltd, St Helens, Lancashire. They will also forward descriptive literature and illustrations.

An excellent way of demonstrating how ordinary glass cuts off the sun's health-giving rays is illustrated in Fig. 37.

The words 'health' and 'disease' are cut out in a piece of cardboard. Over the word 'health' a piece of Vita Glass is laid, and over the word 'disease' a piece of ordinary glass. The pieces of glass are fixed to the cardboard by binding the edges with passe-partout. Tapes are fixed to the back of the cardboard. The apparatus is fixed on the arm when the sun is shining. Under the word 'health' the arm becomes tanned by the sun. Under the word 'disease' the arm is not affected.

Summary of Respiration

Every living thing, plant and animal, is built up of cells consisting of living matter, or protoplasm. This protoplasm can be compared with a machine. A motor-car requires fuel in the form of petrol to provide energy to make it move. This fuel is burned, or oxidized, in the machine and energy is set free. The energy is used to cause movement. Waste substances are formed which escape at the exhaust. One form of energy can be converted into another—*e.g.*, heat can be converted into movement (steam engine), movement into electric currents (dynamo), and electric currents into light (electric lamp), heat (electric fire), or movement (electric train).

Proteins, fats, and carbohydrates (starches and sugars) are foods which are formed by plants, and they also form the food of animals. All these foods contain carbon. During respiration oxygen is taken into the tissues, the foods are slowly oxidized, and energy is set free. The energy may be used for:

- (1) Movement. Animals are continually moving about. Plants do not move so actively, but they use a certain amount of energy when they grow, when shoots turn to the light, and when roots turn towards water, also when flowers open and close their petals.
- (2) Light—*e.g.*, the light of the glow-worm.
- (3) Heat. To keep up the body temperature. In plants and animals combustion is less violent than in the case of a machine—*e.g.*, steam engine—so no great rise in temperature is experienced.

During respiration carbon dioxide and other waste products are given off.

As a proof of the need of oxygen, when attempts were made to climb to the top of Mount Everest oxygen had to be supplied in oxygen cylinders carried on the backs of the climbers, owing to lack of oxygen at high altitudes. Oxygen cylinders are also used by air-men when flying at high altitudes.

In higher animals a special circulatory system is needed to carry oxygen to the cells and to help to get rid of carbon dioxide.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

DETMER, W.: *Practical Plant Physiology*.

FURNEAUX, W. S.: *Life in Ponds and Streams*.

Health Education Year Book, issued by the Central Council for Health Education.

KERR, J.: *Newsholme's "School Hygiene."*

KNIGHT, E. V. M.: *The Golden Science Series*.

LITTLE, W. B.: *Science and Health*.

MELLOR, J. W.: *Introduction to Modern Inorganic Chemistry*.

OSTERHOUT, W. J. V.: *Experiments with Plants*.

PHILIP, J. B.: *Experiments with Plants*.

PHILLIPS, M. E., AND COX, L. E.: *Elementary Biology*.

PHILLIPS, M. E., AND COX, L. E.: *First Book of Biology*.

PORTER, C.: *School Hygiene and the Laws of Health*.

ROWLAND, T. J. S.: *Breathing and Burning*.

ROWLAND, T. J. S.: *Living Things for Lively Youngsters*.

ROWLAND, T. J. S.: *More Living Things for Lively Youngsters*.

STORK, J. W., AND RENOUF, L. P. W.: *Fundamentals of Biology*.

STORK, J. W., AND RENOUF, L. P. W.: *Junior Biology*.

TAYLOR, F. S.: *The World of Science*.

WHIPPLE, A. H.: *Hygiene of the Home*.

WOODHEAD, T. W.: *The Study of Plants*.

See also pp. 59-83 of *Everyday Science Topics*, Book I.

Films

Air and Sun (16mm., silent, 1 reel) (National Association for the Prevention of Tuberculosis).

(Scenes of children in Switzerland above the sun-level. Teaches about open air and the skin and the meaning of sunlight.)

Breathing (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Gives a comprehensive view of the breathing process and its functions.)

- Breathing* (16 mm., silent, 1 reel) (Gaumont British Instructional Films).
(Shows experiments in the chemical process of burning and oxygenation, and illustrates by growing plants that oxygen is essential for life. Various methods of recording the inhalation and exhalation of breath.)
- Circulation* (16 mm., silent, 1 reel) (Gaumont British Instructional Films).
Circulation of the Blood and *The Heart* (16 mm., silent, short-loop films) (Cinepro, Ltd).
- Energy from Sunlight* (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).
- Stand up and breathe* (16 mm., silent, 1 reel) (National Association for the Prevention of Tuberculosis).
(Shows how much fresh air means in business and sport; demonstrates the way it enters the lungs and how it is dealt with there.)
- The Blight of Coal Smoke and a Cure* (16 mm., silent, 2 reels) (British Electrical Development Association).
(Shows the evils of atmospheric pollution by the wasteful burning of coal, and the help which electricity can give in abolishing the smoke nuisance.)
- The Blood* (16 mm., silent, 1 reel) (Gaumont British Instructional Films).
- The Living Cell* (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).
(Presents the important facts concerning the structure and behaviour of cells.)
- The Smoke Menace* (16 mm., sound or silent, 1 reel) (Army Kinema Corporation).

Film-strips

- Air* (Newton and Co., Ltd).
- Respiration and Digestion* (Newton and Co., Ltd).
- The Earthworm* (Common Ground, Ltd).
- The Frog* (Common Ground, Ltd).
- The Human Body* (Army Kinema Corporation).

Lantern-slides

The following organizations will loan sets of lantern-slides:

Garden Cities and Town Planning Association, 13 Suffolk Street, London, S.W.1. (A very large selection of slides is available illustrating all aspects of housing and town planning, and particularly the need for decentralization of large cities into satellite towns. A set of fifty, or less, 10s. 6d. plus carriage.)

Health and Cleanliness Council, Aldwych House, London, W.C.2. (A large stock of slides available, 2s. per dozen, plus carriage each way.)

National Association for the Prevention of Tuberculosis, Tavistock House, North, Tavistock Square, London, W.C.1. (If teachers indicate the line they propose to take in their talks the Medical Commissioner will suggest the most suitable slides; thirty slides 3s., and carriage.)

National Smoke Abatement Society, Chandos House, Buckingham Gate, London, S.W.1. (A stock of over three hundred slides available on loan at a charge of 1d. a slide, plus postage.)

Other Publications

- Biology* (thrice yearly, 1s. 1d. per term, post free for teachers) (British Social Hygiene Council, Tavistock Square, London, W.C.1).
- Biology and Society*, by Professor Julian Huxley (British Social Hygiene Council, Tavistock Square, London, W.C.1).
- Britain's Burning Shame* (National Smoke Abatement Society).
- Fresh Air and Sunshine* (leaflet) (National Association for the Prevention of Tuberculosis).
- Health Guide Card* (British Red Cross Society, 14 Grosvenor Crescent, London, S.W.1).
- Health Guide Charts* (Boy Scouts' Association, 25 Buckingham Palace Road, London, S.W.1).
- Health Laws Card* (British Red Cross Society, 14 Grosvenor Crescent, London, S.W.1).
- How to be Healthy* (leaflet) (Boy Scouts' Association, 25 Buckingham Palace Road, London, S.W.1).
- How to live long and keep Fit* (leaflet) (Boy Scouts' Association, 25 Buckingham Palace Road, London, S.W.1).
- Smokeless Air* (National Smoke Abatement Society).
- The Case against Smoke* (National Smoke Abatement Society).
- The Smokeless Home* (National Smoke Abatement Society).
- Three Schemes for Biology Teaching in Schools* (British Social Hygiene Council, Tavistock Square, London, W.C.1).

Posters

- "Dry Sweeping sends Dust" (National Association for the Prevention of Tuberculosis).
- "For Health's Sake stop that Smoke" (National Smoke Abatement Society).
- "Fresh Air, Moving Air" (National Association for the Prevention of Tuberculosis).
- "Fresh Air, Sunshine, and Exercise" (Youth Hostels Association, Welwyn Garden City, Herts).
- "Health Laws Picture" (British Red Cross Society).
- "Health Life Posters" (British Red Cross Society).
- "Health Posters" (British Red Cross Society).
- "Sleep with your Windows open" (Youth Hostels Association, Welwyn Garden City, Herts).
- "The Healthy Life" (British Red Cross Society).

(E) Fire Extinguishers

A number of preliminary experiments should introduce work on this topic.

(1) Air is necessary for combustion (*Everyday Science Topics*, Book I, p. 84).

(2) To show how much of the air is used during combustion.

(3) *When things burn they combine with oxygen in the air.*

This is an important experiment, as so many pupils believe that when things are burnt they are destroyed and disappear for ever.

A short piece of magnesium ribbon is placed in a crucible with a lid, and the crucible is then weighed. The ribbon is then burnt with the crucible lid almost completely over the crucible, which is mounted on a pipe-clay triangle on a tripod. A small Bunsen flame should be used, and the experiment should not be hurried.

After heating for about half an hour the crucible should be allowed to cool and the whole lot should be weighed again, when it will be found that there is a small increase in weight due to the oxygen which combines with the magnesium during burning.

Oxygen

A little oxygen should be prepared and collected in gas-jars, and pupils should then be shown some common substances burning in air and then in oxygen.

Pupils should realize that if a fire is to be extinguished the supply of oxygen (obtained from the air), necessary to enable the combustion to continue, must be cut off in some way. Different types of fire extinguishers do this in different ways.

The Fire-engine Pump

A model of this special type of pump for pumping water on to a fire, thus surrounding the burning substance with water, cutting off its air-supply and cooling it down, is described in *Everyday Science Topics*, Book I, p. 85. It should be shown that a common force pump emits a jet of water on each downstroke of the piston. For fighting a fire a continuous stream of water is necessary.

The excellent model force pump illustrated at p. 58 of *How and why it works*, by F. Boothroyd, can be converted into a continuous-action or fire-engine pump by the addition of a small flask as illustrated in Fig. 38.

An effort should be made to obtain, for use in the science room, fire extinguishers of every type. Much valuable assistance can usually be obtained from the superintendent of the nearest fire station, and arrangements should be made for the pupils to visit the station.

The best way to get up-to-date information on fire-fighting appliances is direct from the manufacturers. The Pyrene Company, Ltd, Great West Road, Brentford, Middlesex, may be able to supply the following for instructional purposes:

- (1) A large sectional diagram of the "Pyrene" fire extinguishers.
- (2) Particulars and illustrations of the foam type of extinguisher.

- (3) Particulars of the use of the "Pyrene" extinguisher for electrical fires.
- (4) Particulars of the soda-acid type of extinguisher.
- (5) Description of the "Pyrene" extinguisher and method of operation.
- (6) Small quantities of the "Phomene" foam-producing solutions so that the generation of foam can be demonstrated.

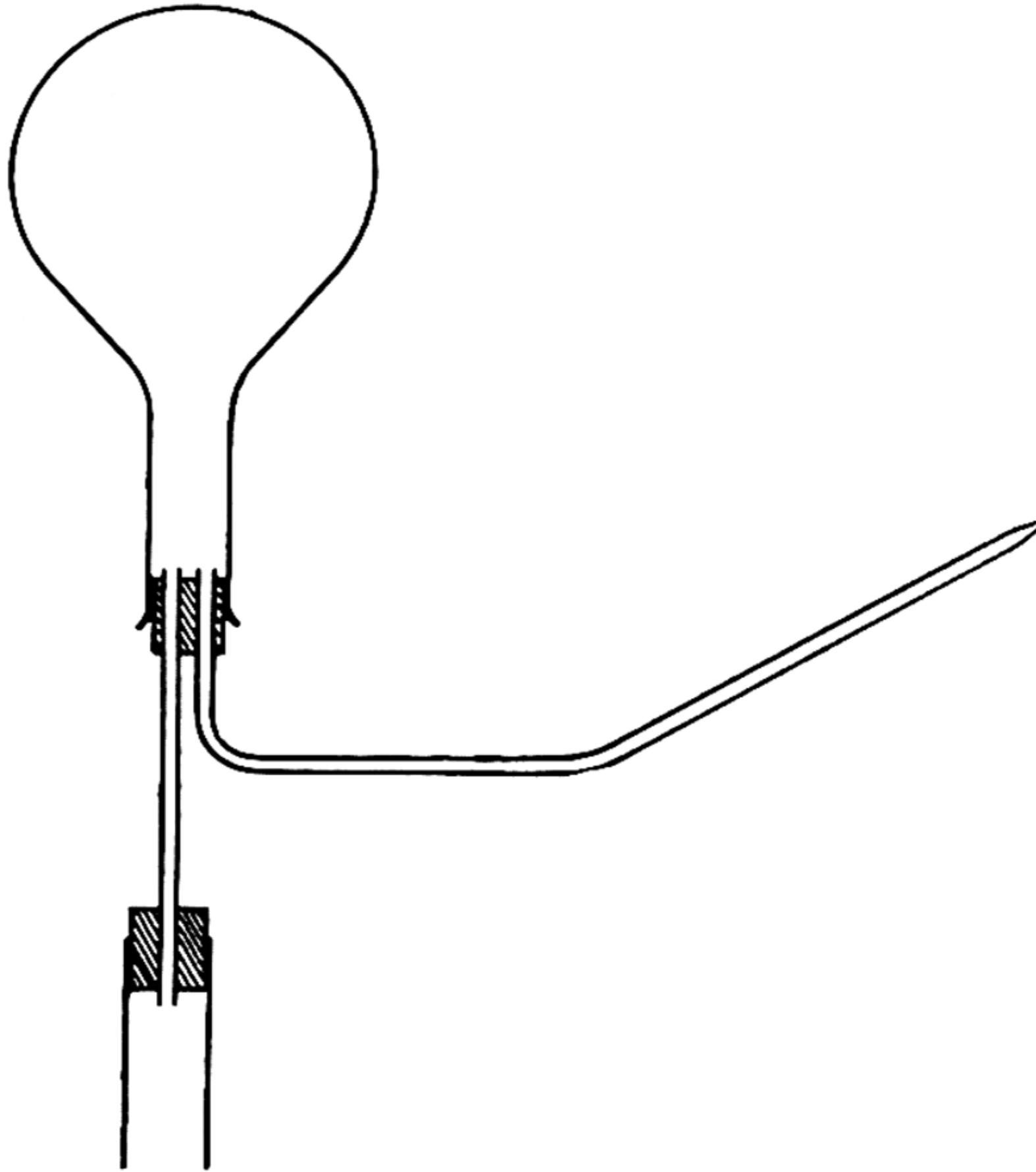


FIG. 38. CONVERTING MODEL FORCE PUMP TO MODEL FIRE-ENGINE PUMP

- (7) A bottle of "Pyrene" fire-extinguishing liquid.
- (8) A handbook, *Modern Fire Fighting*.

Messrs John Kerr and Co., London Road, Northwich, may be able to lend actual fire extinguishers in section and valuable notes for lessons on fire extinguishers. The Walter Kidde Company, Ltd, Belvue Road, Northolt, Middlesex, may supply particulars and illustrations of the "Lux" fire-extinguishing system; Messrs Minimax Ltd, Feltham, Middlesex, a miniature working model of the "Minimax" Type "A" Fire Extinguisher, instruction leaflets describing how to use "Minimax" Extinguishers, and a booklet describing and

illustrating all types of "Minimax" chemical fire extinguishers; Messrs Merryweather and Sons, Ltd, Greenwich Road, London, S.E.10, particulars and illustrations of fire-fighting appliances.

Action of the Break-bottle Type of Extinguisher

It is a good plan to fit a simple oil-pressure gauge to the model fire extinguisher illustrated in Fig. 39 (see Exercise 71 of *Everyday Science Topics*, Book I).

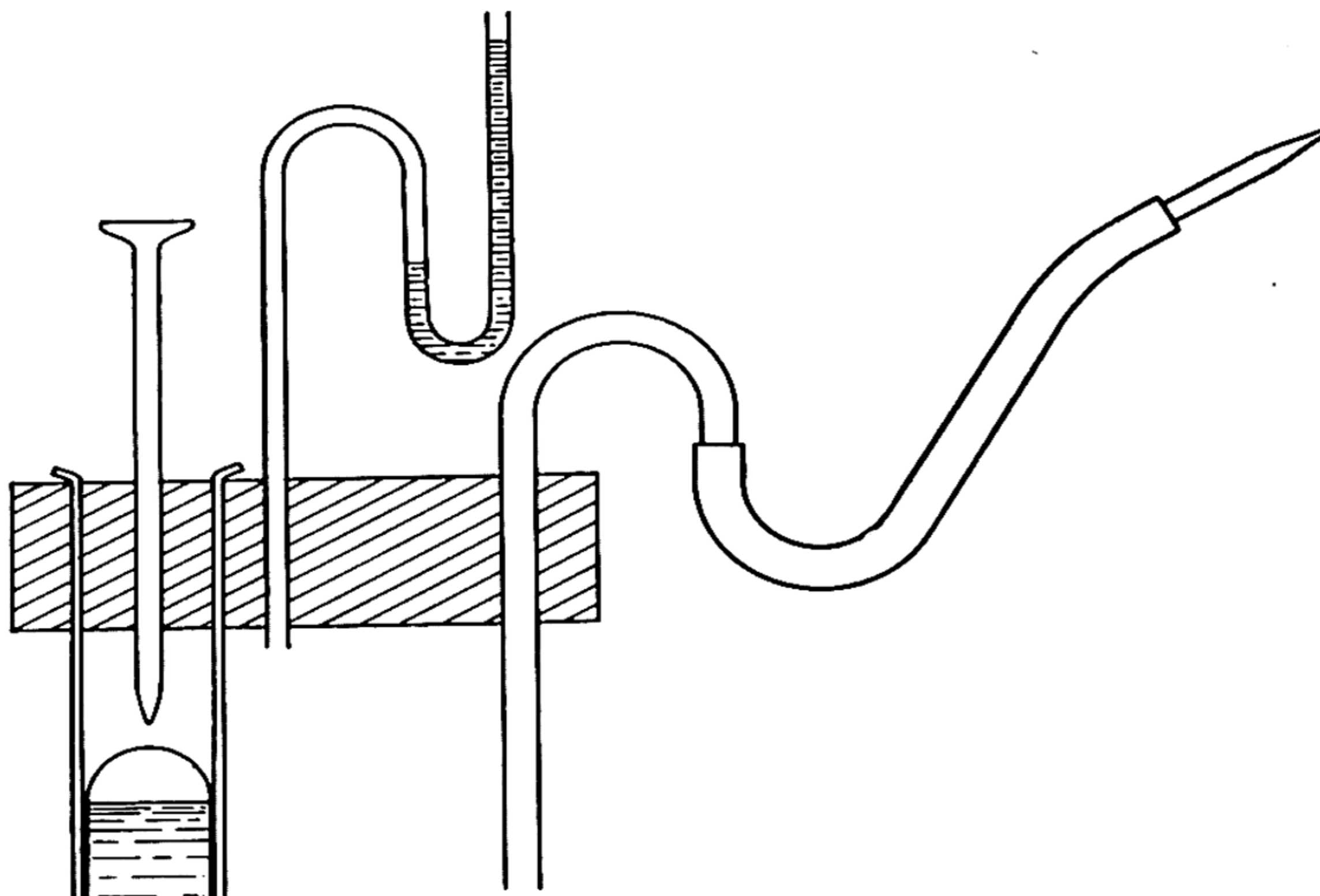


FIG. 39. SIMPLE OIL-PRESSURE GAUGE FITTED TO MODEL EXTINGUISHER

If this is observed when the extinguisher is in action it will be seen how the pressure is highest when the acid first comes into contact with the bicarbonate solution.

This very high initial pressure necessitates the extinguisher being so constructed that it will resist a pressure of some 300–1100 lb. per sq. in. Furthermore, the interior must be protected against corrosion.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

ANNISS, F.: *The New Practical Physics*, Book II.

BEAN, H. E.: *Everyday Science*, Book II.

LITTLE, W. B.: *Science in the City*.

LOW, A. M.: *Popular Scientific Recreations*.

MACDOUGALL, A. T.: *The Marvels of Chemistry*.

MACDOUGALL, A. T.: *The Wonders of Electricity*.

ROWLAND, T. J. S.: *Breathing and Burning*.

RAY, C. (Editor): *The Boy's Book of Popular Science*.

WHIPPLE, A. H.: *Hygiene of the Home*.

See also pp. 84–93 of *Everyday Science Topics*, Book I.

Films

Fire-fighting Materials and their Uses (16 mm., silent, 1 reel) (Educational Films Bureau).

Fire-making (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Demonstrates the dependence of fire upon fuel and oxygen, shows pure oxygen supporting rapid combustion, indicates the kindling points of various substances, gives the history of matches, and depicts the making of modern matches.)

Fire Prevention (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Shows the construction of a fire-resisting building, correct electric insulating, and the proper way to safeguard inflammable material.)

Fire Protection (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Contrasts old and modern equipment and methods of fighting fires. Explains the operation of extinguishers, the principle of cooling, blanketing, or smothering fires, and gives a lesson on fire safety.)

Fire Safety (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Emphasizes the immense annual losses from fire, treats of the ways of preventing fires, and pictures the teaching of fire-prevention methods to children.)

Film-strips

Fireman (Common Ground, Ltd).

Science in Everyday Life—Air Pumps (Army Kinema Corporation).

Science in Everyday Life—Water Pumps (Army Kinema Corporation).

Picture Postcards, Photographs, and Lantern-slides

There are several picture postcards issued by the Science Museum, South Kensington, London, S.W.7, illustrating the development of fire engines. These postcards are excellent for use with the episcopes. Full details of all postcards, photographs, and lantern-slides available at the Science Museum can be obtained from the Director. Most of the topics in the course can be illustrated by means of these Science Museum cards, photographs, and slides. An *Outline Guide to Exhibits in the Science Museum* can also be obtained.

(F) The Magnetic Compass

So much has been written in connexion with this topic that it is difficult to give much information that is really new. Many of the

models described under topic (B) will be useful here. Magnetic compasses of all sizes and designs should be collected for exhibition in the science room.

Perhaps the best way of teaching the use of the magnetic compass is to show pupils how to orientate a large-scale Ordnance Survey map and then find their bearings in a strange place—say, on the moors during a ramble.

Making Magnets

A good supply of clock and gramophone springs and lengths of soft iron wire about $\frac{1}{8}$ in. diameter is necessary when dealing with this topic.

Using lengths of the clock spring and a large solenoid with about 500 turns, pupils can make their own permanent magnets by placing

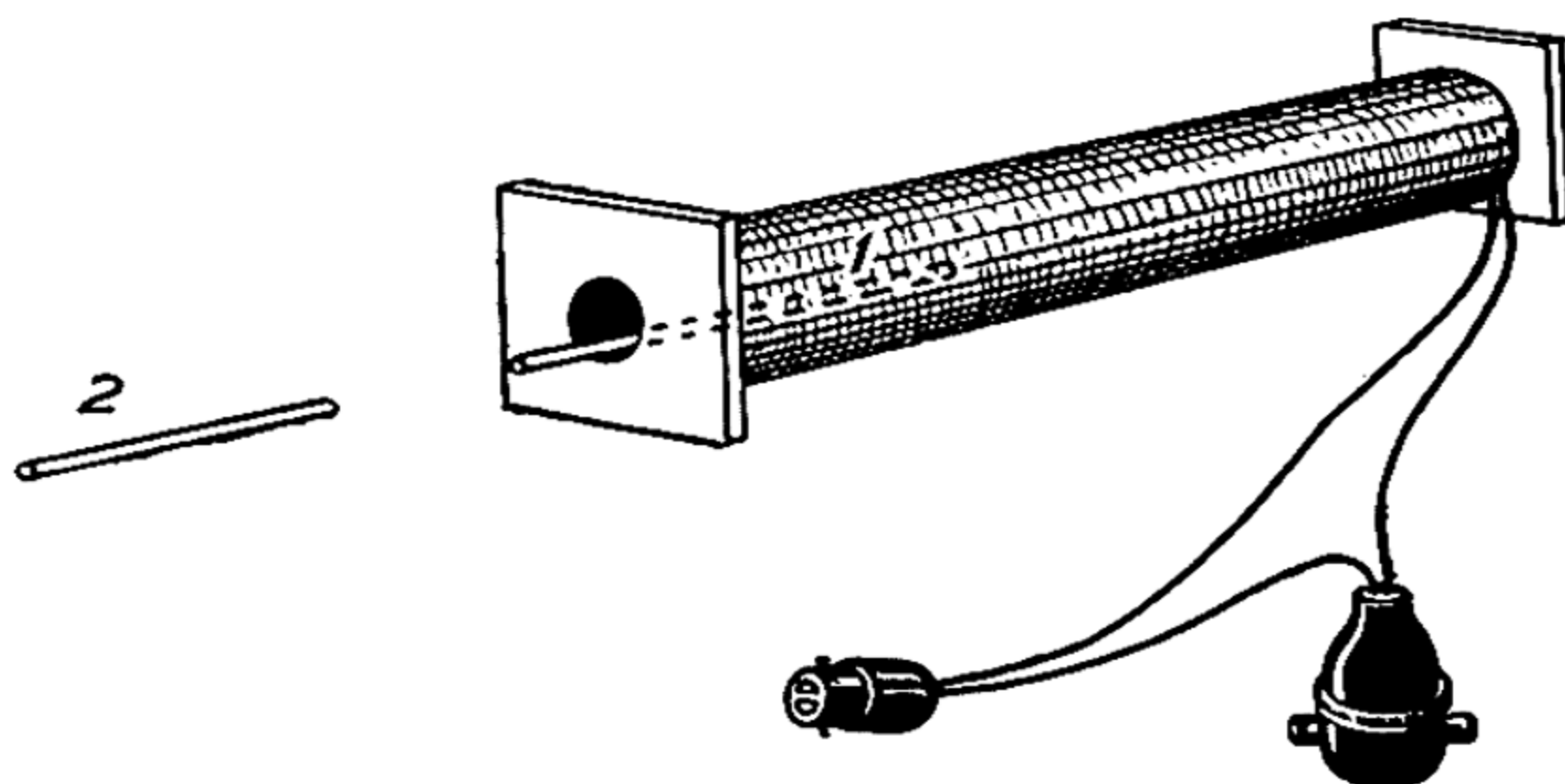


FIG. 40. MAGNETIZING AND DEMAGNETIZING A SILVER STEEL ROD

the pieces of clock spring inside the solenoid when a direct current from a rectifier or battery of accumulators is passing through it.

Good permanent magnets can also be made from silver steel rods which may be obtained from hardware dealers in 13-in. lengths and of various diameters.

Strong permanent laminated magnets can be made from layers of clock spring, each separately magnetized in the 500-turn solenoid and bound together with copper wire. All the north-seeking ends should be kept together.

The horseshoe permanent magnets from magnetos, which can often be obtained from local garages, are excellent for experimental purposes.

Where a direct-current supply is not available many of the experiments in magnetism can be carried out with alternating current.

Alternating current can also be used to magnetize and demagnetize the silver steel rods referred to above. All that is required is a solenoid about 15 in. long and 2 in. internal diameter, with about

eight layers of No. 22 insulated copper wire for a current supply of about 100 volts, which may be obtained from the potentiometer described in Chapter IV.

If the solenoid is to be connected to a 230-volt supply, then a resistance must be placed in series with the solenoid or about sixteen layers of wire must be wrapped on it.

The completed apparatus is illustrated in Fig. 40.

To magnetize a steel rod, place it right inside the solenoid, turn the switch quickly on and off, and the bar will be found to be magnetized.

To demagnetize a magnet place it in the solenoid in position 1, switch on the current, and, with the current passing, withdraw the magnet down the axis of the solenoid to position 2, and then repeat, inserting the other end of the rod in the solenoid.

Model Magnetic Compasses

Fig. 41 shows a method of making an efficient magnetic compass. *A*, *B*, and *C* are similar pieces of clock spring. Each piece is

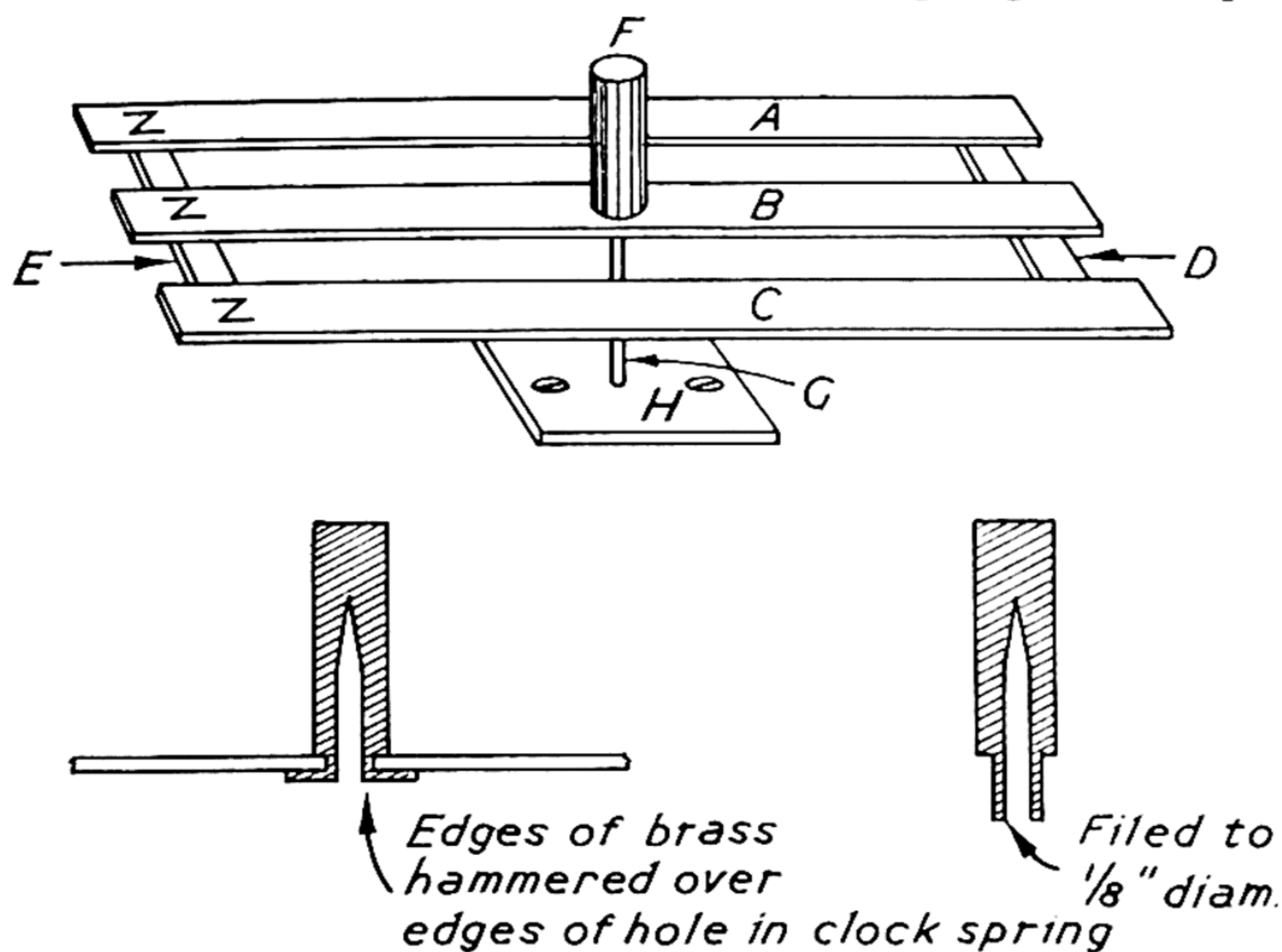


FIG. 41. MAGNETIC COMPASS

magnetized by placing it inside the 500-turn solenoid, and they are fastened together, as illustrated, by strips of copper, *D* and *E*, which are soldered to the pieces of clock spring. *F* is a piece of brass rod about $\frac{3}{16}$ in. diameter. A hole is drilled in this piece of

brass rod, and it is fixed to the central piece of clock spring as illustrated.

G is a gramophone needle or brass pin, soldered to a piece of brass plate, *H*, which is screwed to the bottom of a wooden box. A paper disc with the points of the compass marked on it can be stuck to the upper faces of the pieces of clock spring, and a glass lid placed on the box.

A quick method of making a magnetic compass is to suspend a piece of magnetized clock spring with a piece of cotton in a copper-wire stirrup or float it on a piece of cork in a dish of water.

Suspending Magnets

A good, simple method of suspending heavy bar magnets is illustrated in Fig. 42.

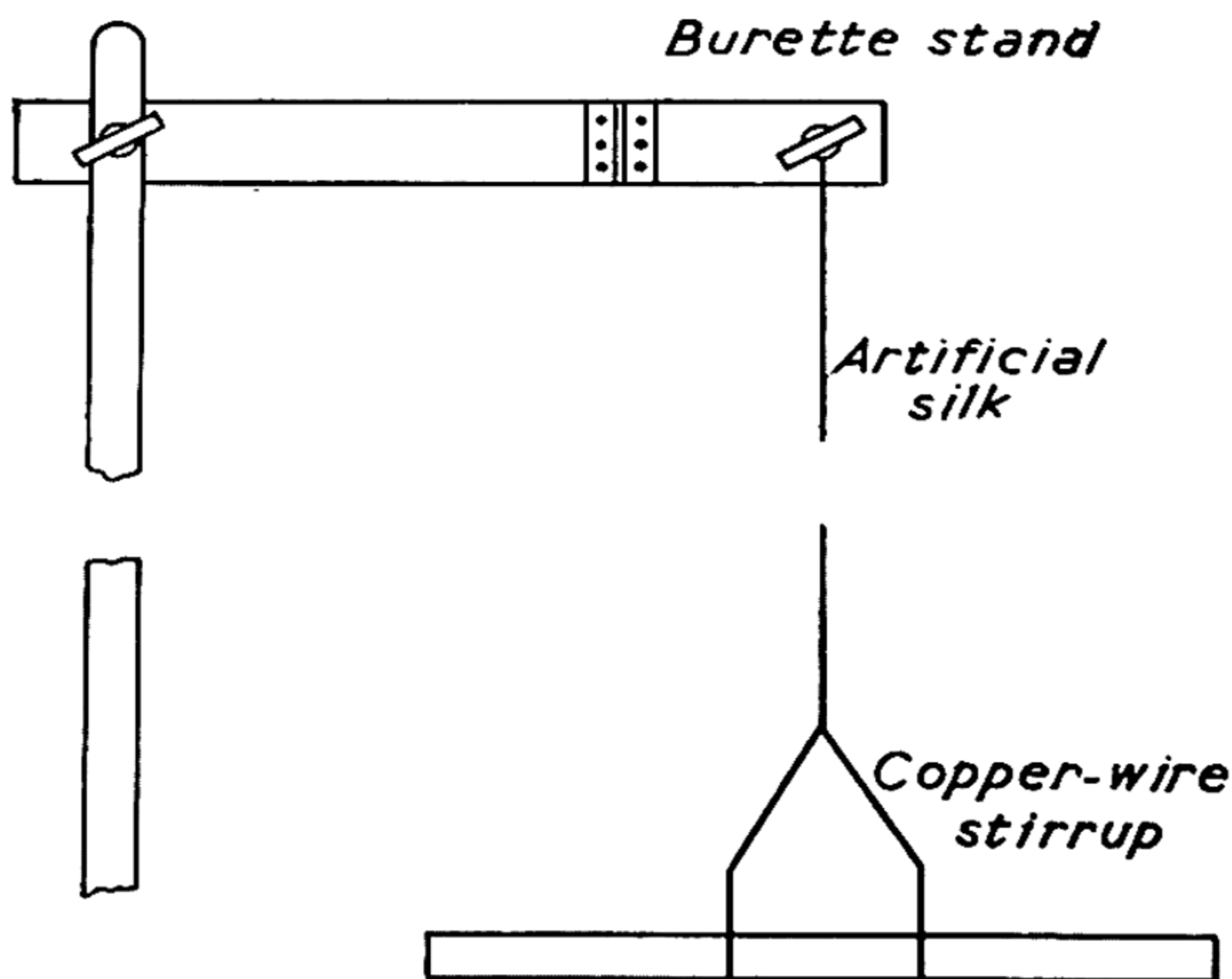


FIG. 42. SUSPENDING A BAR MAGNET

Model Prismatic Compass

Fig. 43 shows how a model magnetic compass, made as previously described, can be converted into a model prismatic compass.

The outer edge of the paper disc, in addition to having the points of the compass marked on it, is marked off in degrees. *A* is a glass prism taken from an old camera and fixed to the brass strip *B* as shown. This strip has a vertical hack-saw cut and a hole about $\frac{3}{16}$ in. diameter. *C* is another strip of brass with a rectangular

portion in the centre cut away and a vertical copper wire fixed at each end with a little solder.

In using the instrument the object it is desired to observe is sighted through the slit in the prism support, and the compass moved about

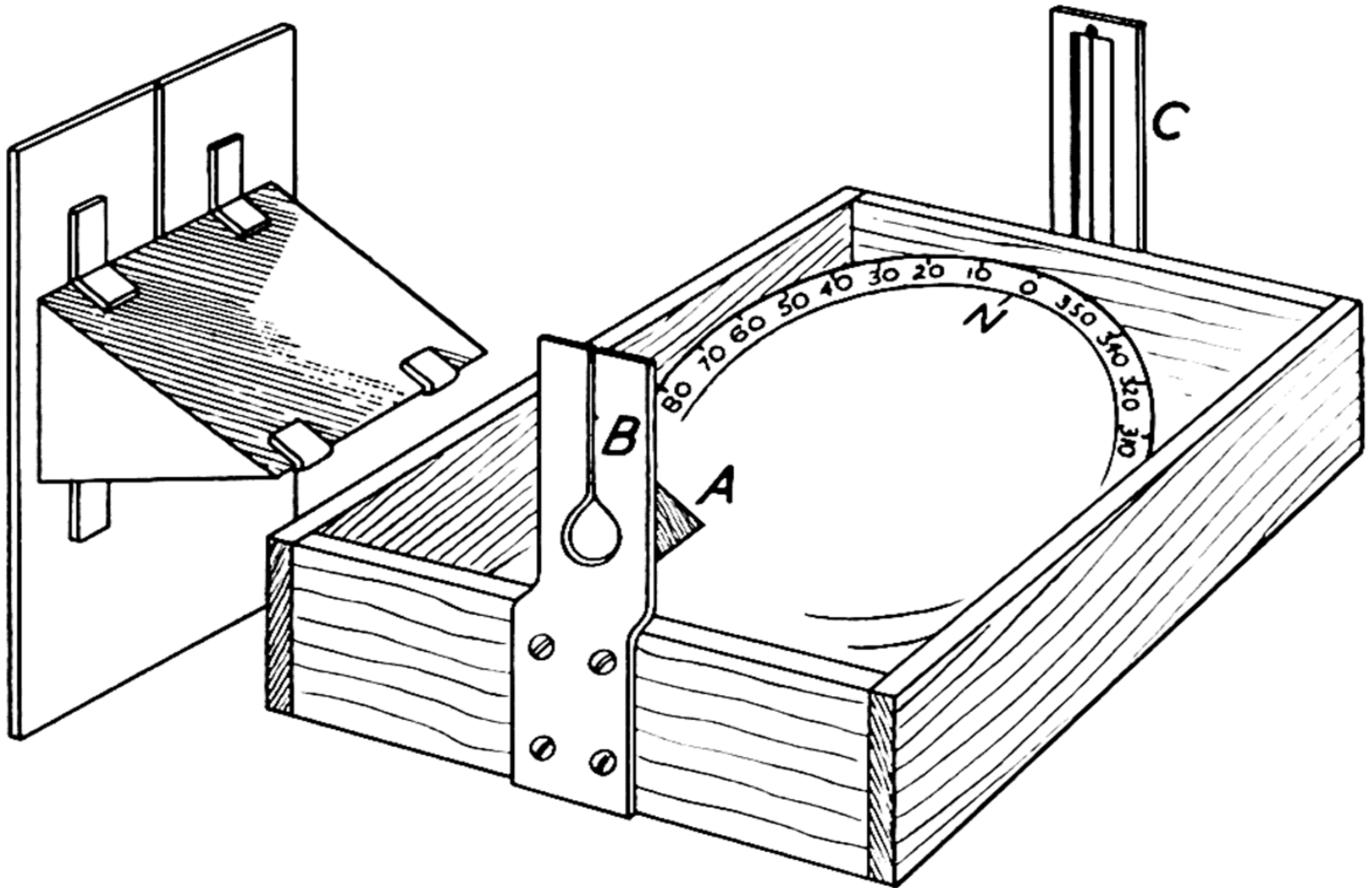


FIG. 43. MODEL PRISMATIC COMPASS

until the vertical copper wire appears to fall on the object. When this is done the point which comes opposite the reading-point in *B* is observed through the prism.

The Use of a Ship's Compass

A fairly large model ship is made of wood (Fig. 44).

A model compass of the type already described is mounted on a shallow plate. On the rim of the plate which represents the binnacle a black line, *A*, is made to represent the lubber-line, which points to the bow of the ship. If the ship is now floated in a large bath tin full of water it can be shown how the sailor keeps his direction,

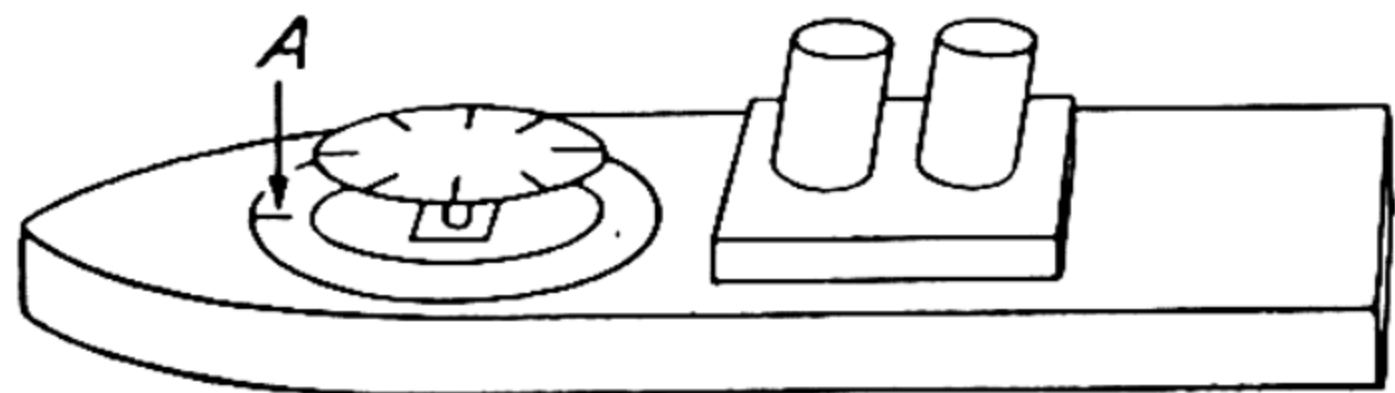


FIG. 44. TO SHOW THE USE OF A SHIP'S COMPASS

Lodestone and the Properties of Magnets

A small specimen of lodestone can usually be obtained from scientific-instrument makers for a few shillings.

In demonstrating the properties of magnets as described in the books mentioned at the end of this section particular emphasis should be laid on those properties which are to be referred to so often in later work on electric motors and dynamos.

Pupils should learn something of the different types of artificial magnets, the law of magnetic repulsion and attraction, methods of magnetization, other than the electrical method already referred to, testing for magnetization (by repulsion only), formation of consequent poles, magnetic substances, magnetic saturation, compound magnets, destruction of polarity, critical temperature, magnetic induction, position of poles, etc.

Temporary, Residual, and Permanent Magnetism

A solenoid with about 1800 turns of insulated wire, of the type described for the model transformer, should have a current of about 1 amp. passed through it. A soft iron rod about 6 in. long and $\frac{1}{4}$ in. diameter is placed inside the solenoid so that it is projecting equally from the ends. When the current is passing the coil becomes magnetized and will support a number of nails at the ends. On breaking the circuit the nails fall off, showing that the magnetism was only temporary during the passage of the current.

If the above procedure is repeated with iron filings in place of nails some of the filings are retained after the current is switched off. This is due to residual magnetism in the core, a very small amount of which is retained after the magnetizing current has ceased.

When the iron core is replaced by a similar steel rod and the above experiments are repeated most of the nails and filings are retained after the current is switched off, showing that the steel retains most of its magnetism after the magnetizing field has been removed.

To show how Steel loses its Magnetism when made Red-hot

AB is a 10-in. length of fine steel wire. A length of fine piano wire will serve the purpose. This wire should be magnetized by placing it inside the 500-turn solenoid. It is then held at each end between a brass terminal and washer. That it is magnetized can be demonstrated by bringing a compass needle near one end.

A current of about five amps. is passed through the wire. This should be sufficient to make it red-hot.

When the compass needle is now held near one end of the red-hot wire it will be seen that the magnetism has disappeared.

*The Difference between a Magnetized and an
Unmagnetized Piece of Steel*

To demonstrate the difference between a magnetized and an unmagnetized piece of steel, take a glass tube $\frac{3}{8}$ in. in diameter and closed at one end, and nearly fill it with fairly large steel filings. The open end should be closed with a rubber bung.

The tube should then be placed in the 500-turn solenoid and the current switched on. When the tube is gently shaken the filings will be seen to arrange themselves parallel to the length of the tube.

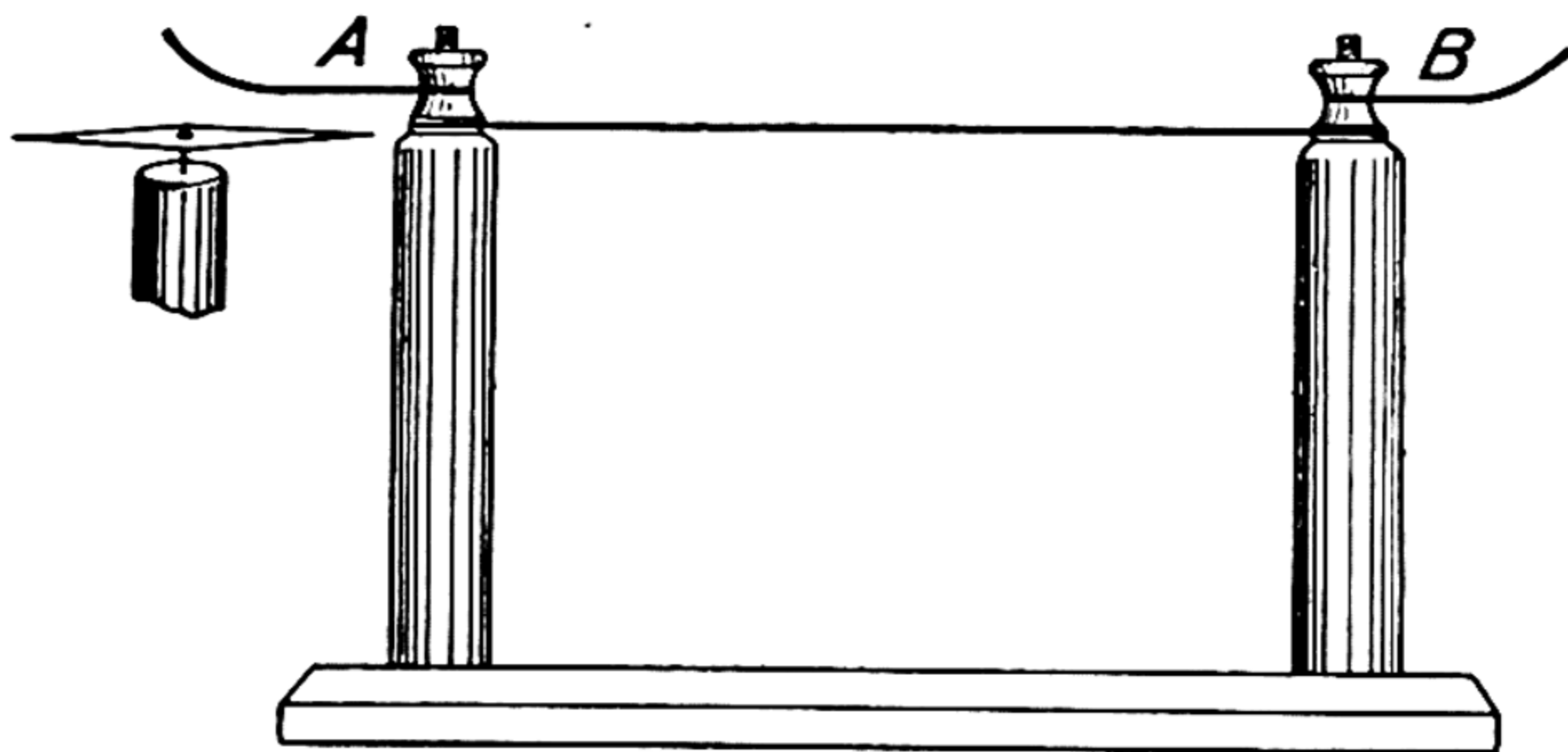


FIG. 45. TO SHOW HOW RED-HOT STEEL LOSES ITS MAGNETISM

When the tube is carefully removed from the solenoid it has all the properties of a permanent magnet, but when it is shaken up it loses these properties, thus demonstrating how rough treatment destroys magnetism.

The filings can be seen aligning themselves if the glass tube is stroked from end to end with one end of a strong bar magnet.

A Powerful Mains Electro-magnet

A strong electro-magnet can be made by using the U-shaped laminated core, the short laminated core, and the 1800-turn solenoid from the model transformer described at p. 71 of *Everyday Science Topics*, Book II. The solenoid is placed in position over one arm of the U-shaped core and connected to a 230-volt supply. The current is switched on, and the short, straight core is brought near the ends of the U-shaped core. When about half an inch away it is pulled with great force on to the U-shaped core, and it is almost impossible to pull it off.

Valuable illustrations and information on the industrial uses of electro-magnets may be obtained from the Igranic Electric Co., Bedford.

How to remagnetize Magnets

It will sometimes be found that after a time permanent magnets weaken. If a strong horseshoe electro-magnet is available it is quite a simple matter to remagnetize bar or horseshoe permanent magnets by the method shown in Fig. 46.

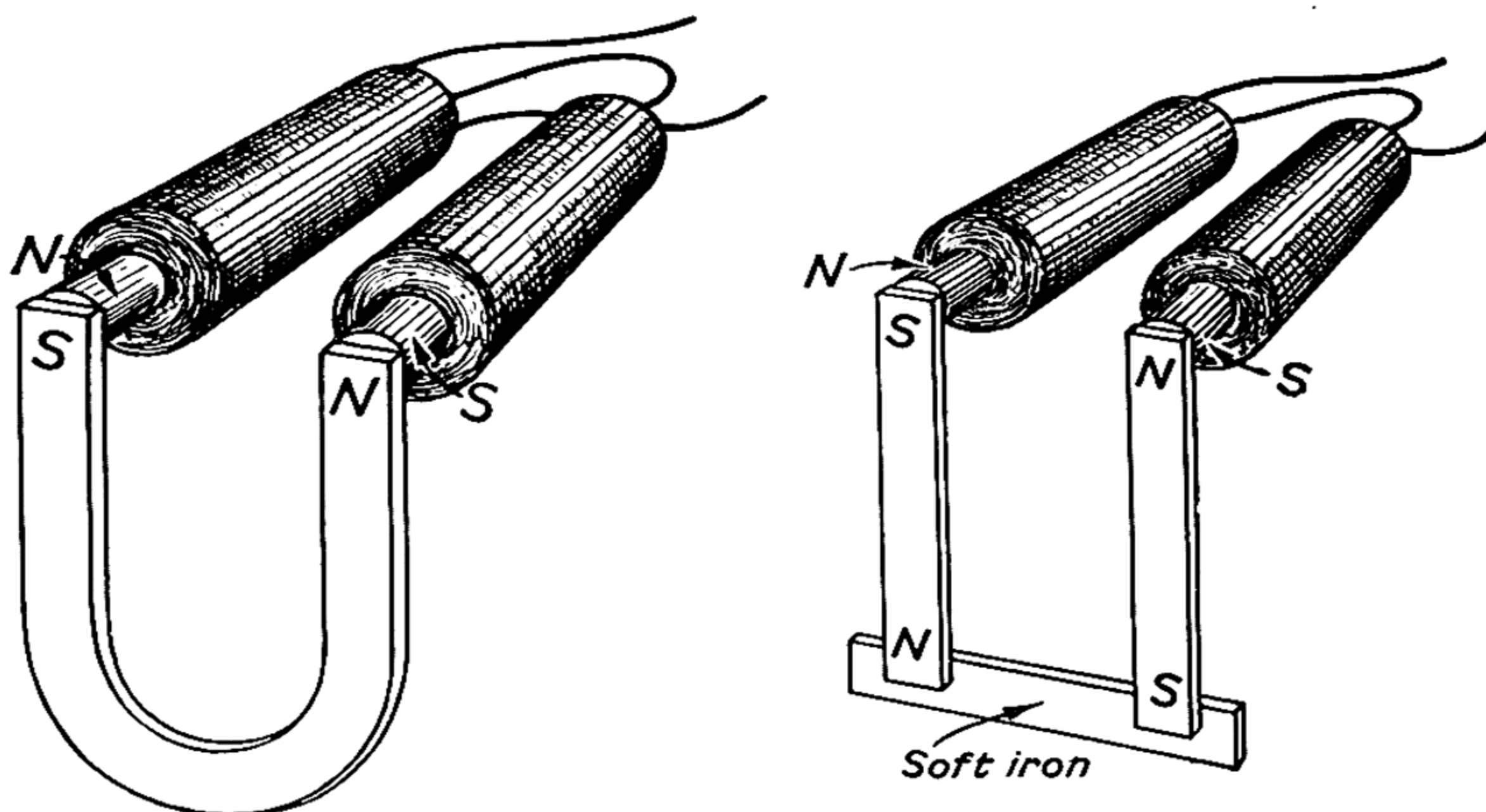


FIG. 46. REMAGNETIZING WEAK MAGNETS

A strong current should be switched on for a few seconds, when the magnets will be found strongly magnetized again.

A Model Dip-needle

This is shown in Fig. 47. *A* is a circular piece of plywood which has a short piece of dowelling fixed in a hole made in its centre. This piece of dowelling fits in a hole made in the wooden base so that the plywood *A*, the upper surface of which is graduated in degrees, can be rotated freely. *B* and *C* are two brass strip uprights screwed to the plywood *A*. The method of holding the magnetized steel needle is illustrated in the smaller diagram. *D* is a piece of plywood graduated in degrees, and fixed with screws to the upright *B*.

Magnetic Fields

A board for the rapid demonstration of magnetic fields in a horizontal plane using iron filings is shown in Fig. 48.

A is a piece of wood about 9 by 14 inches to which is fastened, by hinges, a wooden frame, *B*, covered on the upper side with a piece of thin white smooth cardboard, which is fastened to the frame by a

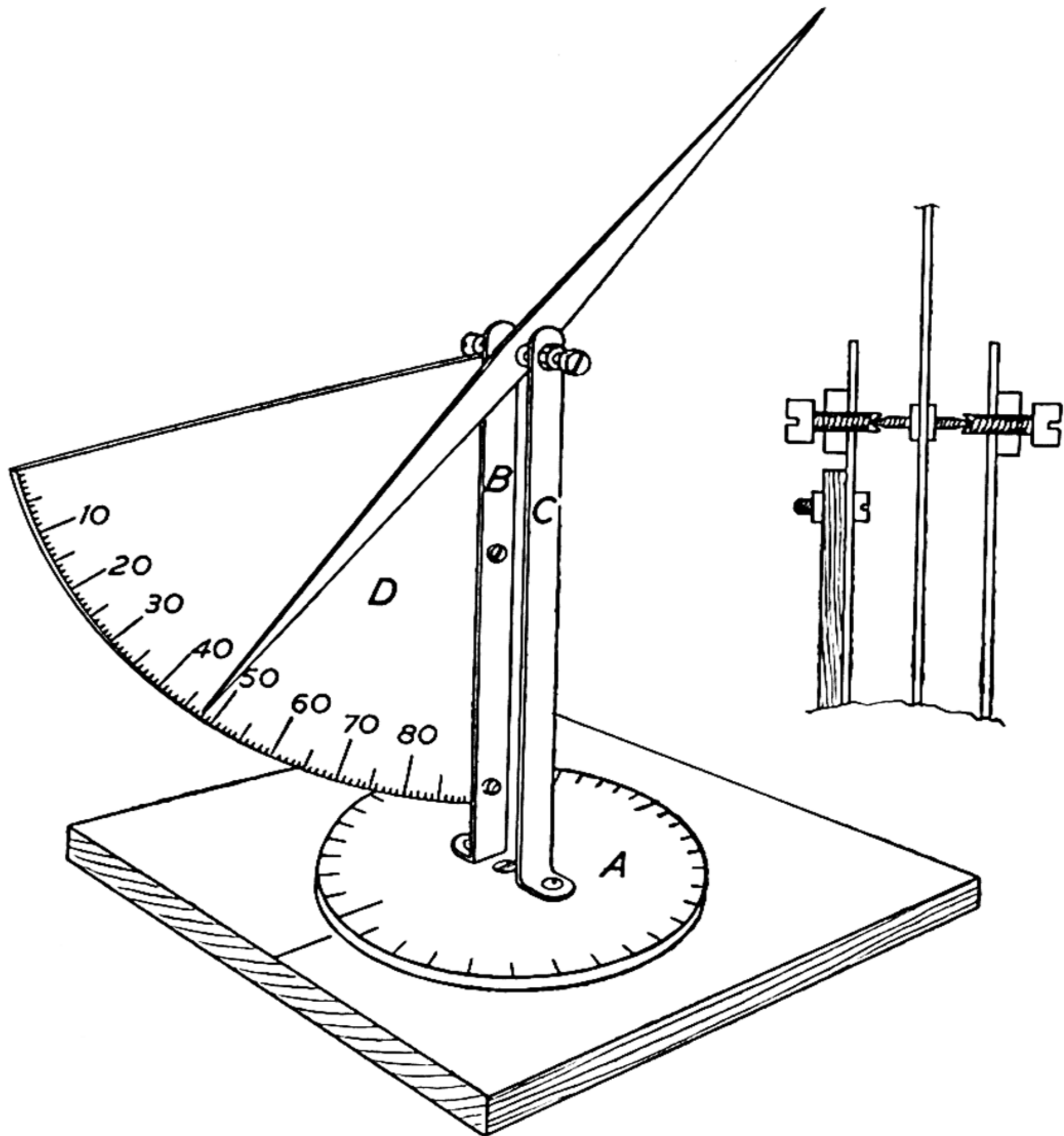


FIG. 47. A MODEL DIP-NEEDLE

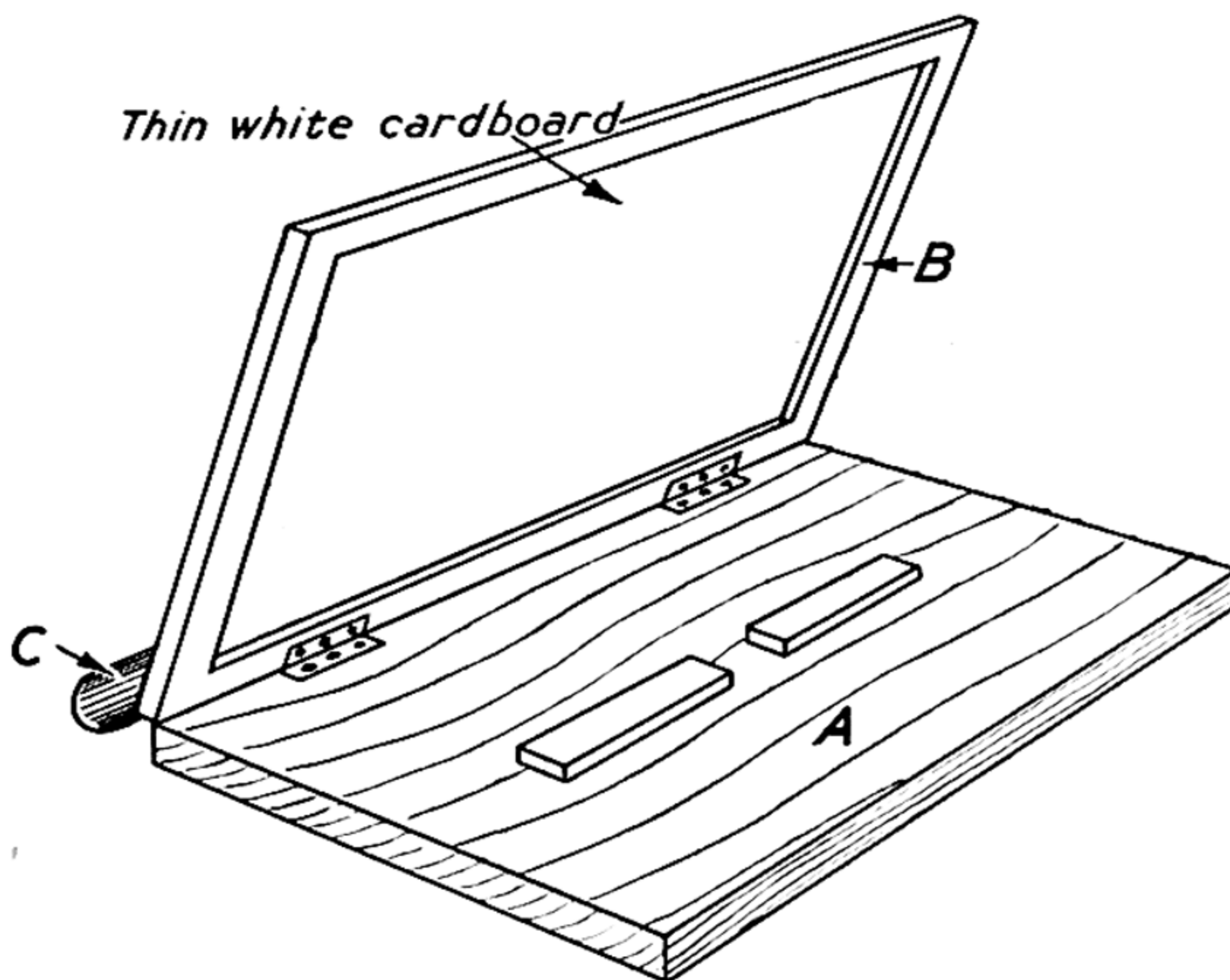


FIG. 48. BOARD FOR DEMONSTRATING MAGNETIC FIELDS

few brass tacks. *C* is a trough made from thin brass plate and fastened by brass screws to the frame.

The magnets are placed on the board *A*, the frame is shut down, and iron filings are scattered from a pepper-holder over the white cardboard. The card should be lightly tapped with a pencil to enable the filings to get into their correct positions.

When the magnetic field has been examined the frame *B* is raised, the filings fall into the trough, and can be quickly poured back into the pepper-holder.

Permanent Records of Magnetic Fields

To make permanent records of magnetic fields pieces of plain white paper should be placed in a shallow tin containing melted paraffin wax, carefully withdrawn, and the wax allowed to solidify so that the surface of the paper is perfectly smooth.

The paper can then be placed on the thin white card of the model in Fig. 48.

Iron filings are scattered over the surface of the waxed paper, and when the alignment is good a Bunsen flame should be moved quickly backward and forward over the paper until the wax melts. It is then allowed to solidify again, and thus hold the filings in position, giving a permanent record of the magnetic field.

In addition to records of the magnetic fields of the usual arrangements of bar and horseshoe magnets, the following records should also be made:

- (1) A piece of soft iron in between unlike poles.
- (2) Magnetic screening of a point, *A*, by using (i) a thick slab of soft iron, *B*; (ii) a soft iron cylinder, *C*.

Projecting Magnetic Fields on to the Screen

A most fascinating way of showing the nature of magnetic fields is to project them on to a screen. An optical lantern is required, and the simple model lantern described in Chapter VI is excellent for this purpose.

A suitable glass trough for this experiment can quite easily be made as shown in Fig. 50.

The glass can be sealed in position with putty, and if the wood is given a good coating of paint inside and out and allowed to dry for a considerable time the cell will be quite watertight. It should be made just large enough to fit into the place usually occupied by the slide-carrier in the lantern.

For projecting magnetic fields it is filled with glycerine, some iron

filings are dropped in, and the magnet or magnets inserted. The iron filings move slowly into position towards the poles of the magnet.

Another method of projecting magnetic fields on to a screen is to

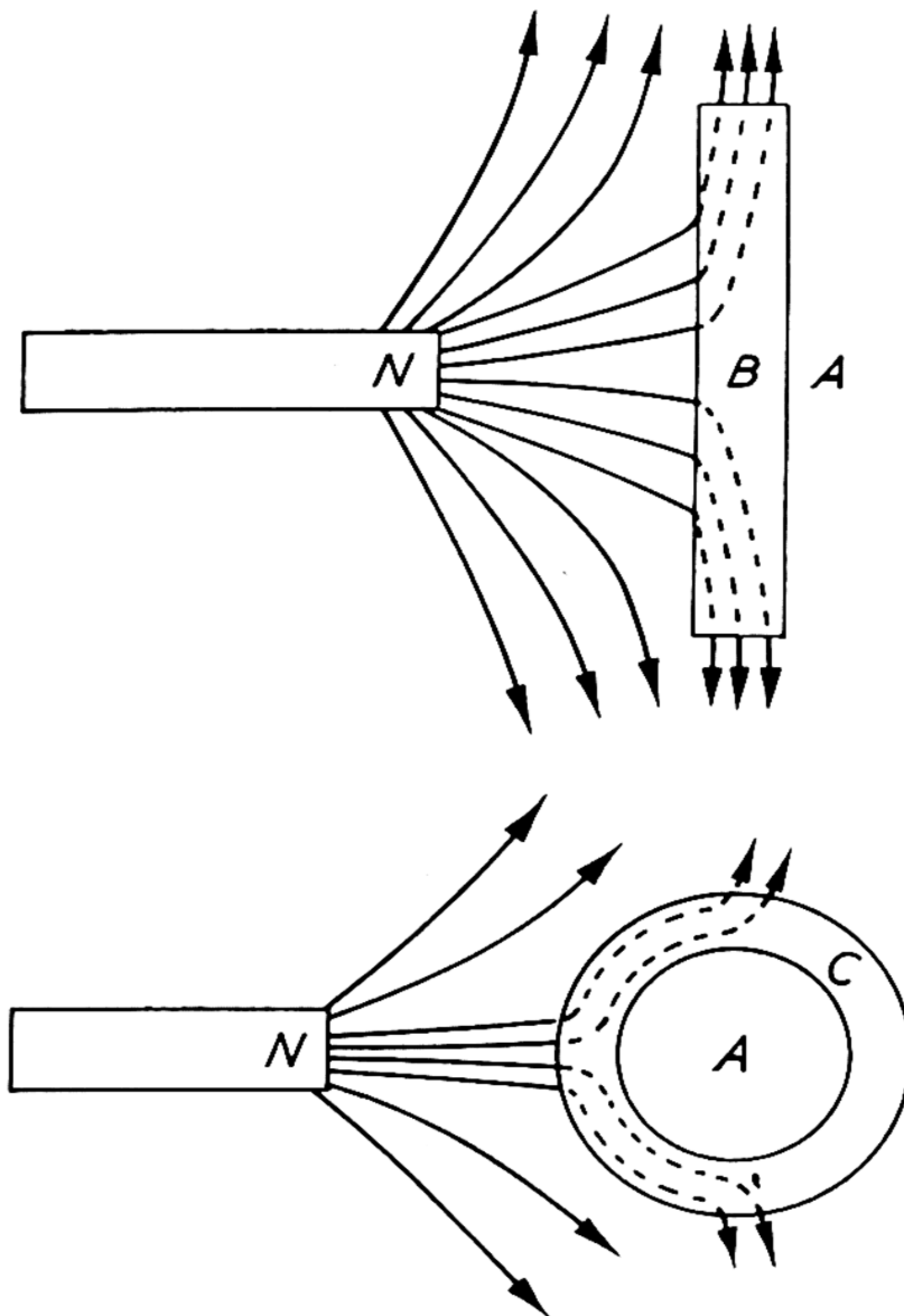


FIG. 49. MAGNETIC SCREENING

use small magnets about $\frac{3}{4}$ in. long and $\frac{3}{16}$ in. diameter fixed with wax to the underside of pieces of glass.

Iron filings are sprinkled on the upper side of the glass, and the arrangement of the filings can be projected on to a screen by using the optical lantern in a vertical position, so that the glass is horizontal.

The picture can be projected direct on to the ceiling or a mirror

can be placed at 45° to the axis of the lantern object if it is desired to project on to a vertical screen.

Magnetic lines of force in relief can be obtained by placing a piece of cardboard over the poles of a strong horseshoe electro-magnet. Iron filings are dropped on to the cardboard from a short distance above and the card lightly tapped.

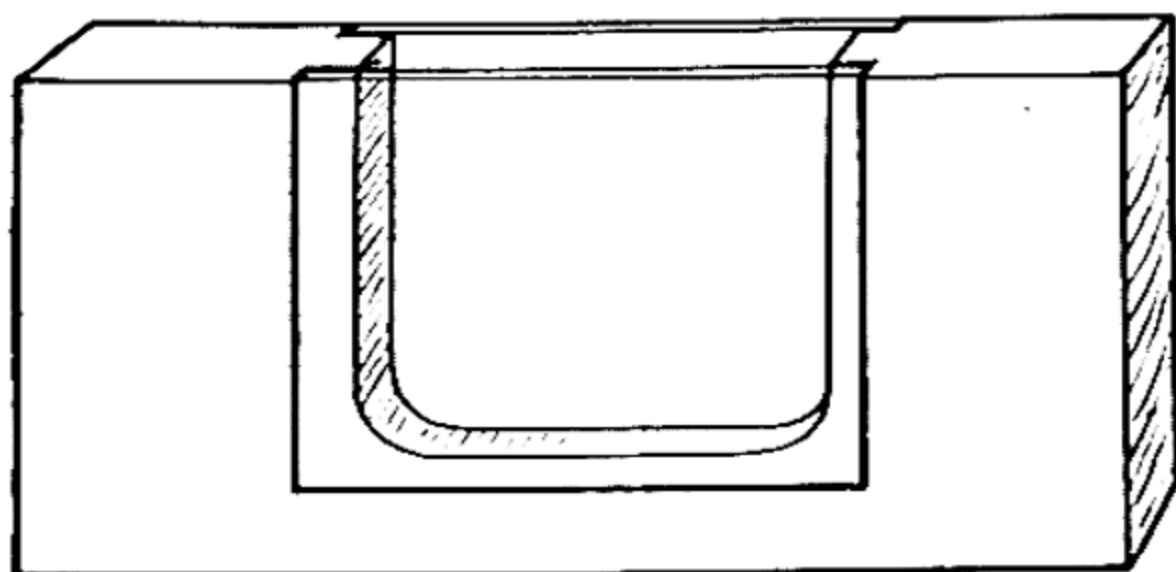


FIG. 50. GLASS TROUGH FOR PROJECTING

The cardboard is then sprayed with a thin solution of shellac or warm paraffin wax. The sprays given away with some insecticides are excellent for this purpose.

Measuring the Strengths of Permanent Magnets and Electro-magnets

Fig. 51 illustrates a rough method of comparing the pole strengths of magnets.

A is a cylindrical permanent bar magnet suspended by means of two pieces of cotton from two brass strip supports so that its height can be adjusted according to whether a permanent bar magnet or an

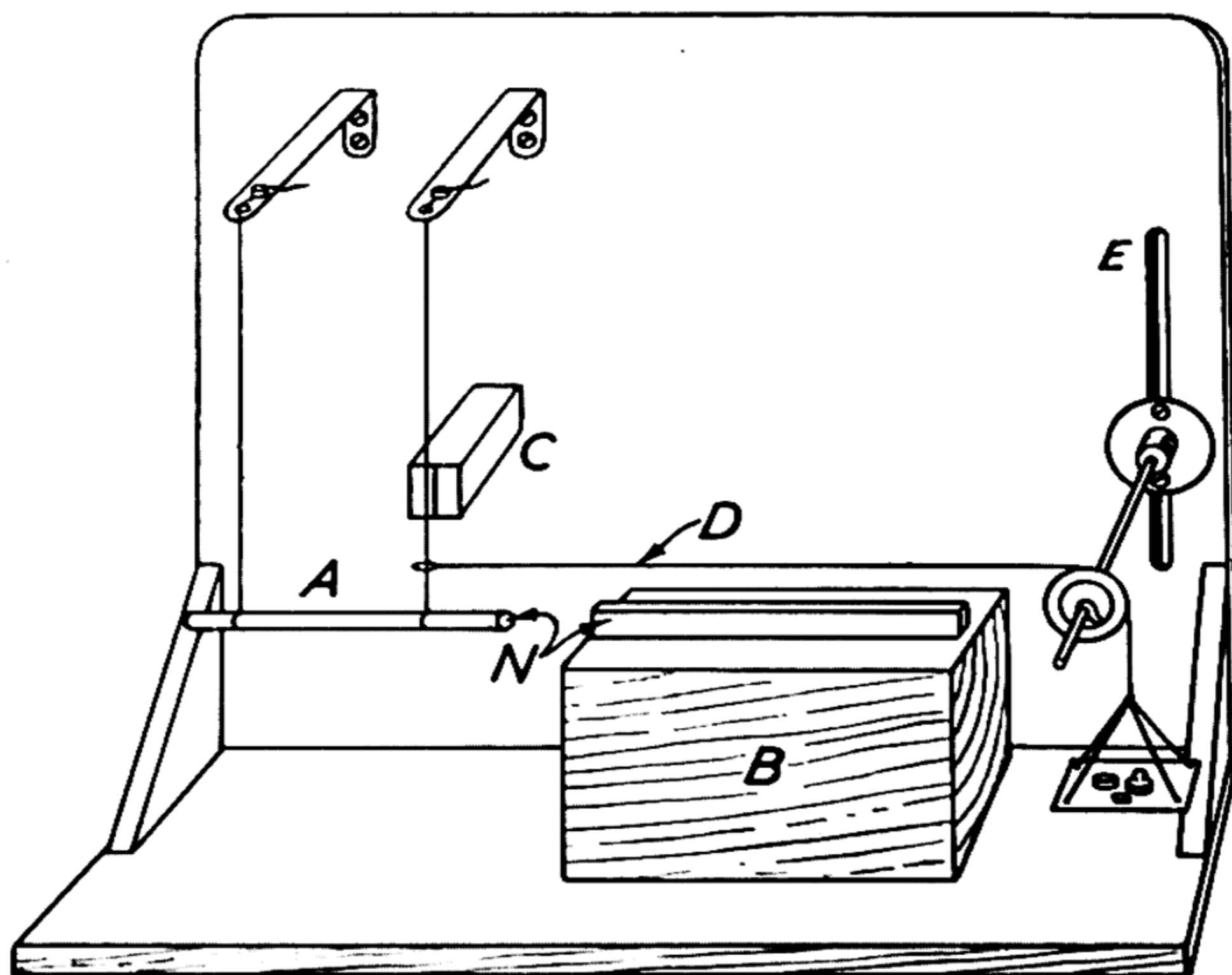


FIG. 51. APPARATUS FOR COMPARING THE POLE STRENGTHS OF MAGNETS

electro-magnet is laid on the block of wood *B*. A vertical line is marked on the piece of wood *C* directly behind one of the pieces of cotton when there is no magnet on *B*. Another piece of cotton, *D*, is looped round one of the pieces supporting the magnet *A*, and this passes over the Meccano pulley, the height of which can be adjusted in the groove *E* by using two Meccano bush-wheels, one on each side of the vertical board, bolted together. The force of repulsion between the magnet poles is balanced by placing weights in the light cardboard scale-pan until the vertical cotton support is directly in line with the vertical mark on *C*.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

- ANDRADE, E. N. DA C., AND HUXLEY, J.: *Forces at Work*.
 ANNISS, F.: *The New Practical Physics*, Book III.
 BEAN, H. E.: *Everyday Science*, Book I.
 BRAY, F.: *Elementary Science*, Book II.
 CUTTING, T. A.: *Electric Fun*.
 DE RATTI, A.: *Simple Scientific Experiments*.
 DUCKWORTH, E. H., AND HARRIES, R.: *The Laboratory Workshop*.
 FOURNIER, E. E.: *Wonders of Physical Science*.
 LITTLE, W. B.: *General Elementary Science*.
 LOW, A. M.: *Popular Scientific Recreations*.
 LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book I.
 MACDOUGALL, A. T.: *The Wonders of Electricity*.
 MANFIELD, G. W.: *Practical Science for Seniors*, Book II.
 MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.
 RAY, C. (Editor): *The Boy's Book of Popular Science*.

See also pp. 94–110 of *Everyday Science Topics*, Book I.

Films, Photographs, Lantern-slides, etc.

There are a number of lantern-slides and photographs obtainable from the Science Museum, South Kensington, London. Full particulars can be obtained from the Director.

Magnetic Effects of Electricity (16 mm., silent, 1 reel) (Wallace Heaton).
 (Includes magnetism and magnetic induction, with their application to the electro-magnet, the theory of permanent magnetism, and an explanation of terrestrial magnetism.)

Magnetism (16 mm., sound, 1 reel) (Elec. Devel. Assoc.).

Film-strips

Magnetism (Centurion Film-strips).

Magnetism (Newton and Co., Ltd).

The Magnetic Field (Newton and Co., Ltd).

(G) The Flash-lamp

As many different types of flash-lamps and cycle lamps as possible should be available.

Large sectional drawings of flash-lamps showing the position of the battery terminals, switches, and lamps are a great help.

The Electrano plug-board apparatus is excellent for clear demonstration of lamp circuits. The lamps and switches can be fastened by screws to the wooden strips. Full particulars of Electrano apparatus can be obtained from the Electrano Company, BCM/Electrano, London, W.C.1.

Information on electric lamps and their manufacture was obtained from the British Thomson-Houston Company, Ltd, Crown House, Aldwych, London, W.C.2.

Further information was obtained from Messrs Philips Electric Lamps, Ltd, Century House, Shaftesbury Avenue, London, W.C.2, and from the Lighting Service Bureau of the Electric Lamp Manufacturers' Association, 2 Savoy Hill, London, W.C.2.

Why there must be no Air inside an Electric Lamp

The necessity for pumping out all the air from electric lamps can be demonstrated in the following way.

Take about 2 cm. of tungsten filament from an old lamp or from samples supplied by manufacturers. Support this between two terminals and pass an electric current through it in series with a rheostat. Gradually increase the strength of the current, and it will be observed that before it is strong enough to heat up the filament to incandescence the tungsten fuses and drops like powder on to the bench.

The remarkable strength of the filament can also be shown by supporting quite a considerable weight by means of it.

An interesting way to demonstrate the low pressure inside an electric lamp and at the same time to show that air has weight is to support a 60-watt electric lamp by means of a piece of cotton from one arm of a balance.

Place weights on the other scale-pan until the lamp is carefully balanced. The balance should be shielded from draughts. By means of a Bunsen flame and a blowpipe a small pointed flame can then be concentrated on the lamp. When the glass is molten the air rushes in, carrying the molten glass with it. The balance pointer moves to the right, indicating that the lamp with its contained air is heavier than before.

Curved Reflectors

The action of curved reflectors used in flash-lamps can be demonstrated in a horizontal plane with the aid of a strip of brass, tin plate, or stainless steel about 2 in. wide and 14 in. long. This should be bent into the shape of a parabola, and, if tin plate or brass is used the inside surface should be well polished.

Place a large sheet of drawing-paper on the bench and a lighted 12-volt lamp in the centre of the sheet. The pupils will easily realize

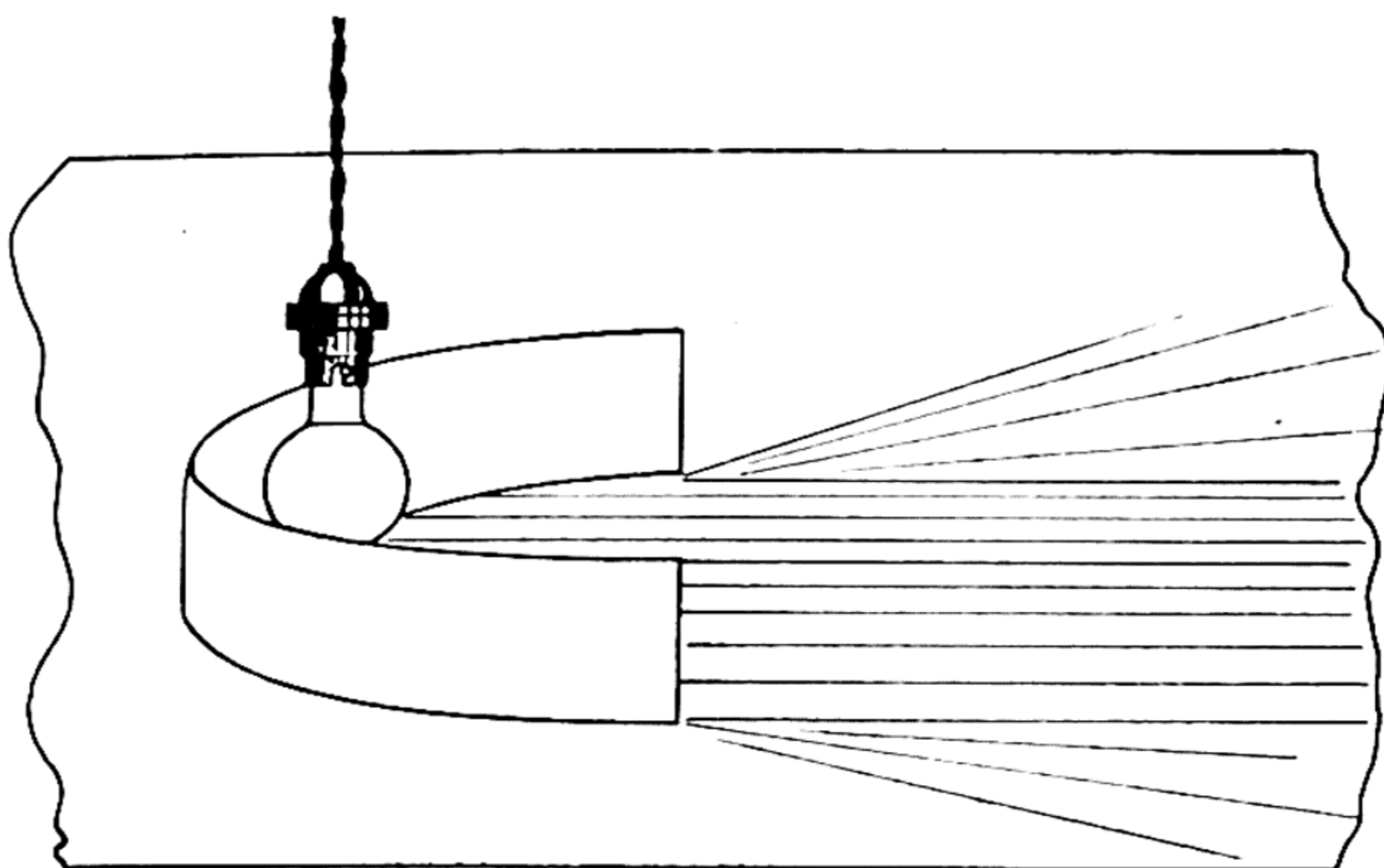


FIG. 52. DEMONSTRATING THE ACTION OF REFLECTORS

how the light spreads out over a wider area the greater the distance from the lamp, and consequently how the intensity of illumination diminishes with increase of distance from a source of light.

Now place the lighted lamp inside the metal plate reflector as illustrated, and the pupils will see that when the lamp is placed in a certain position (the focus of the reflector) there is a parallel beam of light which penetrates to a considerable distance, and a fainter beam which spreads just in front of the reflector. In this way near and far objects are illuminated.

When demonstrating the action of the reflectors used in certain types of flash-lamps it is helpful to have one or two large reflectors from motor-car headlamps. These can usually be obtained from garages, and serve many useful purposes in the science room. They will send a powerful beam of light across the room, and they can be used for making model electric fires and for experiments on the reflection of heat and sound as described in connexion with later topics.

The Action of the Lenses

The action of the lenses in certain types of flash-lamps can be demonstrated by using the same arrangement of apparatus as illustrated in Exercise 100 of *Everyday Science Topics*, Book I.

The diverging beam of light which emerges from the slit in the optical box can be made into a parallel beam by using cylindrical convex lenses. With a long focus lens (a thin lens) the optical box has to be placed far away from the lens to produce a parallel beam. If a fat lens is used (two plano-convex lenses together) the optical

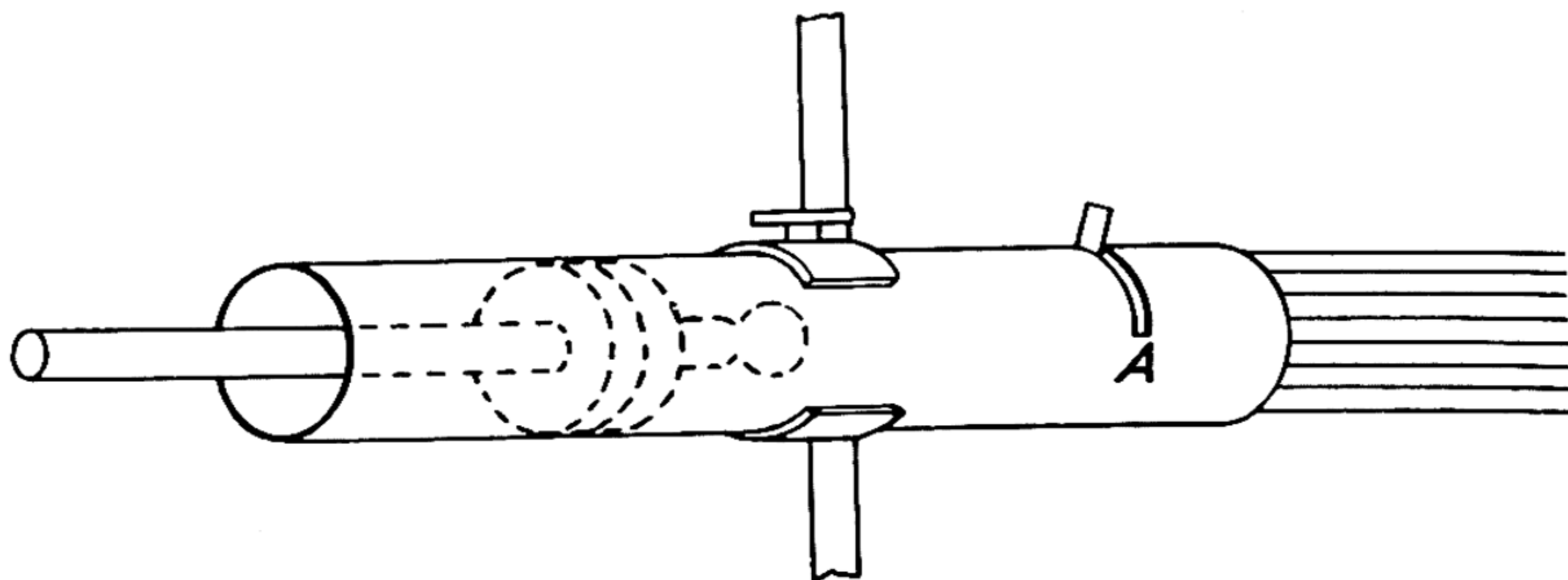


FIG. 53. DEMONSTRATING THE ACTION OF LENSES

box must be nearer to the lenses. Pupils will thus see why lenses on flash-lamps are usually so fat.

Beakers filled with water make quite good cylindrical lenses, especially if a layer of black paper is floated on the water. Different focal lengths can be obtained by using different sizes of beakers. In the same way flasks filled with water can be used as spherical lenses.

The action of lenses can also be demonstrated by using a length of brass, cardboard, or ebonite tubing, a miniature lamp-holder fixed to a wooden base, spherical lenses, and a sheet of white paper fixed vertically to act as a screen.

A length of dowelling is fixed to the wooden lamp-holder base. A piece of the tubing is cut out with a hack-saw at *A* so that lenses of various focal lengths can be dropped into the end of the tube. Pieces of thick paper are fixed to the edges of the lenses so that they can be held in position and removed easily when necessary.

Without lenses in the tube pupils see how the diverging beam forms a large circle of light of low intensity on the screen. When lenses are dropped into the tube and the position of the lamp is adjusted the pupils see the small circle of light of high intensity.

A Model Optical Bench and Accessories

Fig. 54 shows a simple model bench for demonstrating the action of lenses, and made from a metre rule and a few pieces of wood.

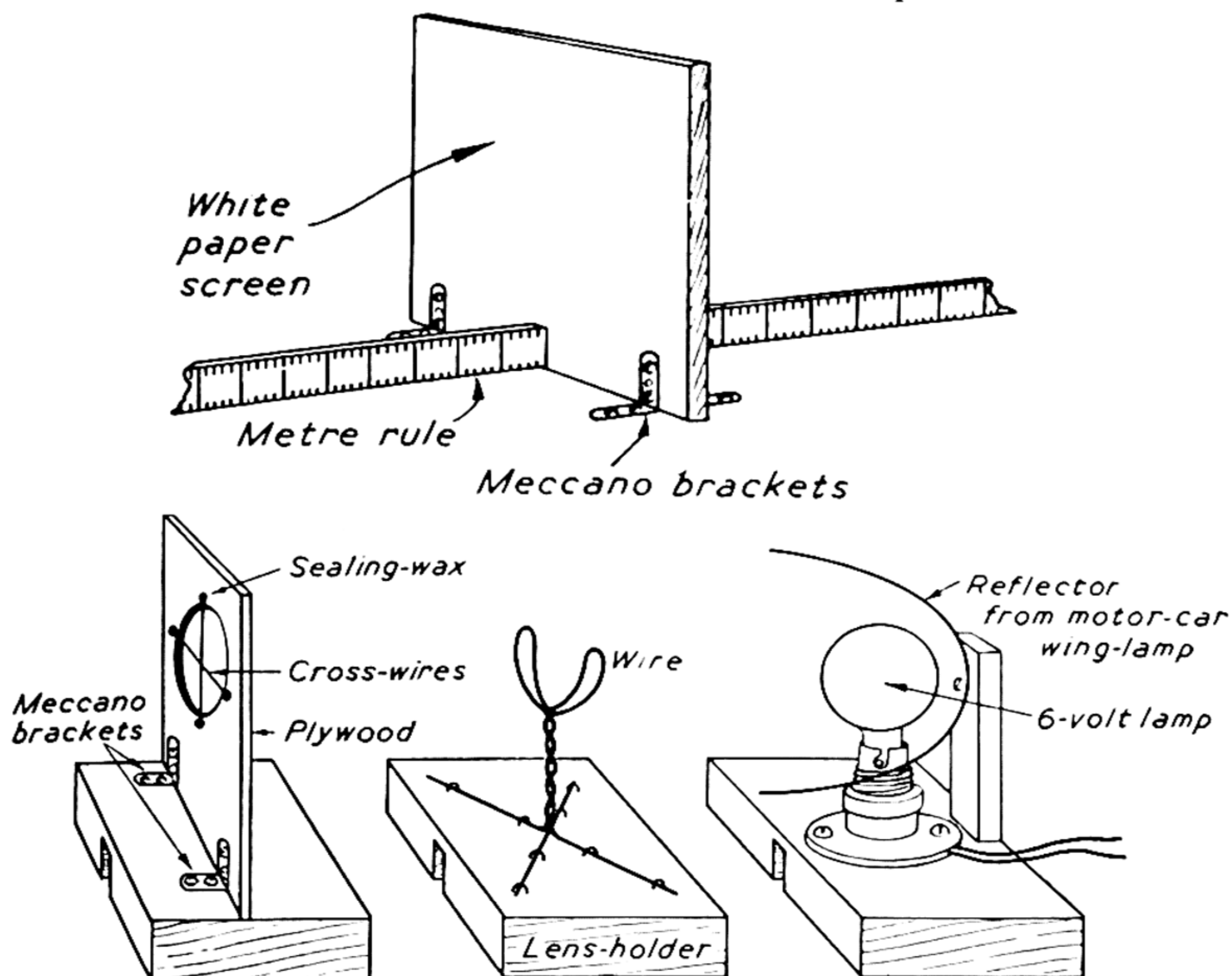


FIG. 54. MODEL OPTICAL BENCH AND ACCESSORIES

Parallel Beam Apparatus

Excellent pieces of apparatus for demonstrating before a class, in a vertical plane, the action of mirrors and lenses, are described in *The Laboratory Workshop* and *The Science Master's Book*, Series II, Part I. The optical ray demonstration apparatus described at p. 102 of the latter book has the additional advantage of enabling the pupils to make rapid readings of angles, thus making it possible for them quickly to verify the laws of reflection and refraction.

Refraction Apparatus

This apparatus is designed to show the bending of light when it passes from one medium to another.

A fairly large rectangular glass jar is required. This should be completely covered on the outside with dead-black paper, except at A,

where a narrow slit should be made in the paper, and at *B*, where a circle about 4 in. in diameter should be cut out. If dead-black paper cannot be obtained the jar can be covered on the outside with a solution of lamp-black in bleached shellac. A ring of white paper graduated as illustrated should be fixed round the circular opening *B*. A parallel beam of light can be concentrated on the horizontal slit *A* by using an optical box as described in *Everyday Science Topics*,

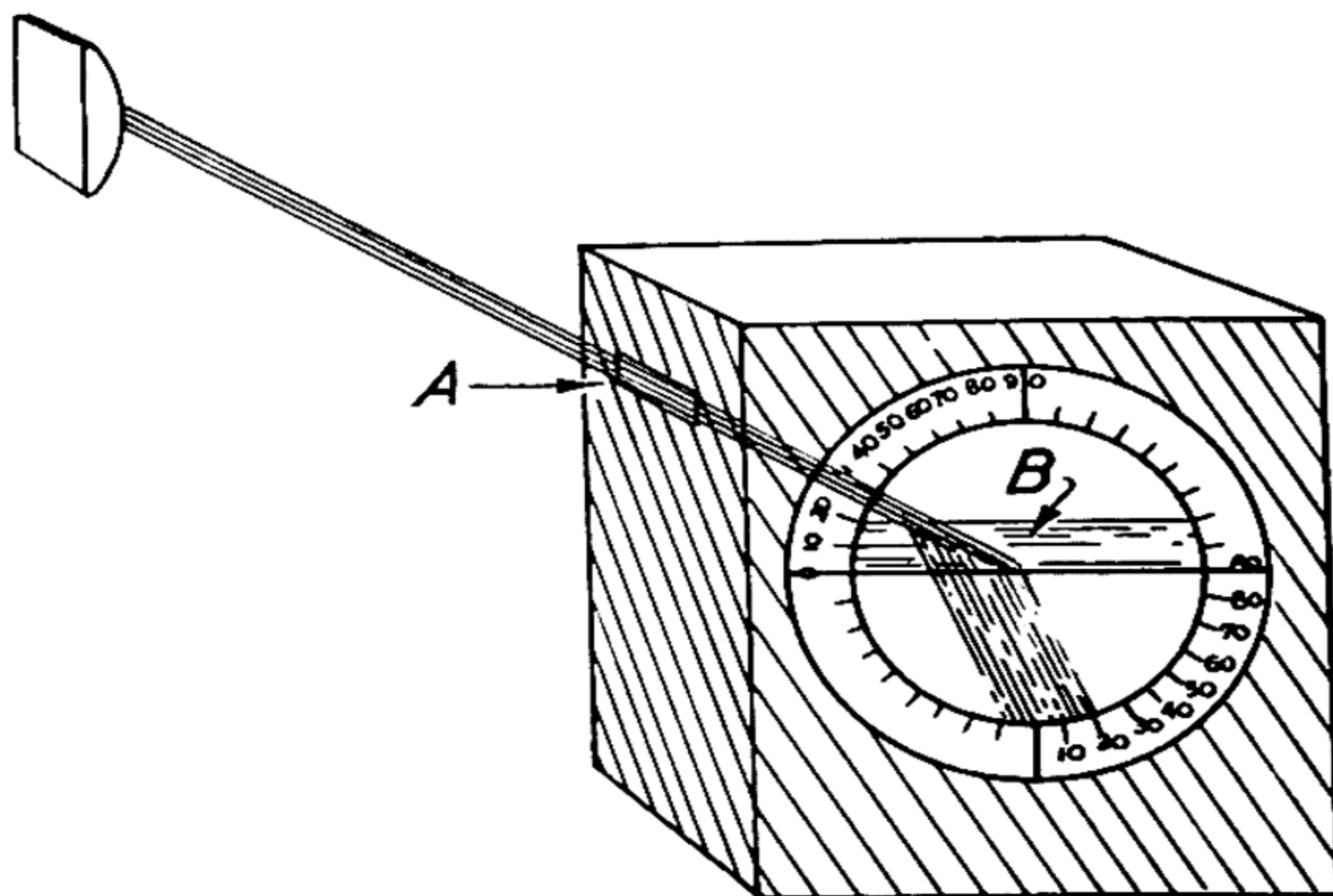


FIG. 55. APPARATUS FOR SHOWING THE REFRACTION OF LIGHT

Book I, but with a horizontal slit and a cylindrical convex lens in the position illustrated. This beam of light should meet the surface of the water placed in the jar as in the illustration. The water-level should be along the horizontal line 0° to -90° , and a little fluorescein or red ink should be mixed with the water. The bending of the light as it meets the surface of the water is easily seen, and the amount of bending can be measured. The experiment requires a darkened room.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

- ADLAM, G. H. J. (Editor): *The Science Master's Book*, Series II, Part I.
 DUCKWORTH, E. H., AND HARRIES, R.: *The Laboratory Workshop*.
 LITTLE, W. B.: *General Elementary Science*.
 LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book III.
 MACDOUGALL, A. T.: *The Wonders of Electricity*.

MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.

ROYDS, A.: *How it acts*.

See also pp. 111–122 of *Everyday Science Topics*, Book I.

Films

Lenses (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Reflection of Light: Parallel Beam—Plane Mirror; Radial Beam—Plane Mirror (16 mm., silent, loop film) (Dance-Kaufmann).

The Behaviour of Light (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

The Searchlight Projector (16 mm., sound, 1 reel) (Army Kinema Corporation).

Transmission of Light: Through a Plate; Through a Convex Lens (16 mm., silent, loop film) (Dance-Kaufmann).

Film-strips

Experiments with Light Rays (Newton and Co., Ltd).

Light (Newton and Co., Ltd).

Light—Its Propagation, Reflection, and Refraction (British Industrial Films and Army Kinema Corporation).

The Story of the Electric Lamp (Newton and Co., Ltd).

(H) The Vacuum Flask

A number of vacuum flasks of various types should be available, and they should be dismantled to show the construction and to enable the pupils to examine the glass vessel. One or two partly broken glass vessels are useful to show the double walls and the silvering on the vacuum side of the glass walls. Photographs of four early heat-insulation vessels devised by Dewar are contained in a pamphlet, *Historical Apparatus*, "Modern Science Memoirs," No. 8 (John Murray). The earliest flasks and tubes in which liquefied gases were collected were surrounded by glass jackets, the intervening space being kept dry by means of a desiccating agent placed in the outer vessel; this was to prevent the deposition of an opaque layer of frost in the inner tube. The inner vessel was held in position by means of cork or soft wax. Later the space between the two vessels was evacuated by means of an air pump.

The vacuum between the two glass walls can be demonstrated by concentrating a blowpipe flame on the outer wall. When the glass is molten the air pressure will push inward the molten glass and the air will be heard rushing in.

To demonstrate the efficiency of the vacuum in a vacuum flask equal quantities of hot water should be poured into a good flask and into a flask without a vacuum, made by heating the outer glass wall in a blowpipe flame as described in the last paragraph. Thermo-

meters should be placed in the flasks and the mouths closed with cotton-wool plugs. The temperature of the water in each flask should be noted at regular intervals, and graphs showing the rate of cooling should be constructed.

The low conductivity of glass can be demonstrated by holding a piece of glass rod in a Bunsen flame. In the flame the glass will soon become molten, while about an inch away from the flame the glass is cool enough to touch. The experiment should be repeated with a copper rod. It is even more convincing to allow a pupil to hold in a Bunsen flame a length of copper wire and a piece of glass rod and allow the other pupils to observe which he drops first.

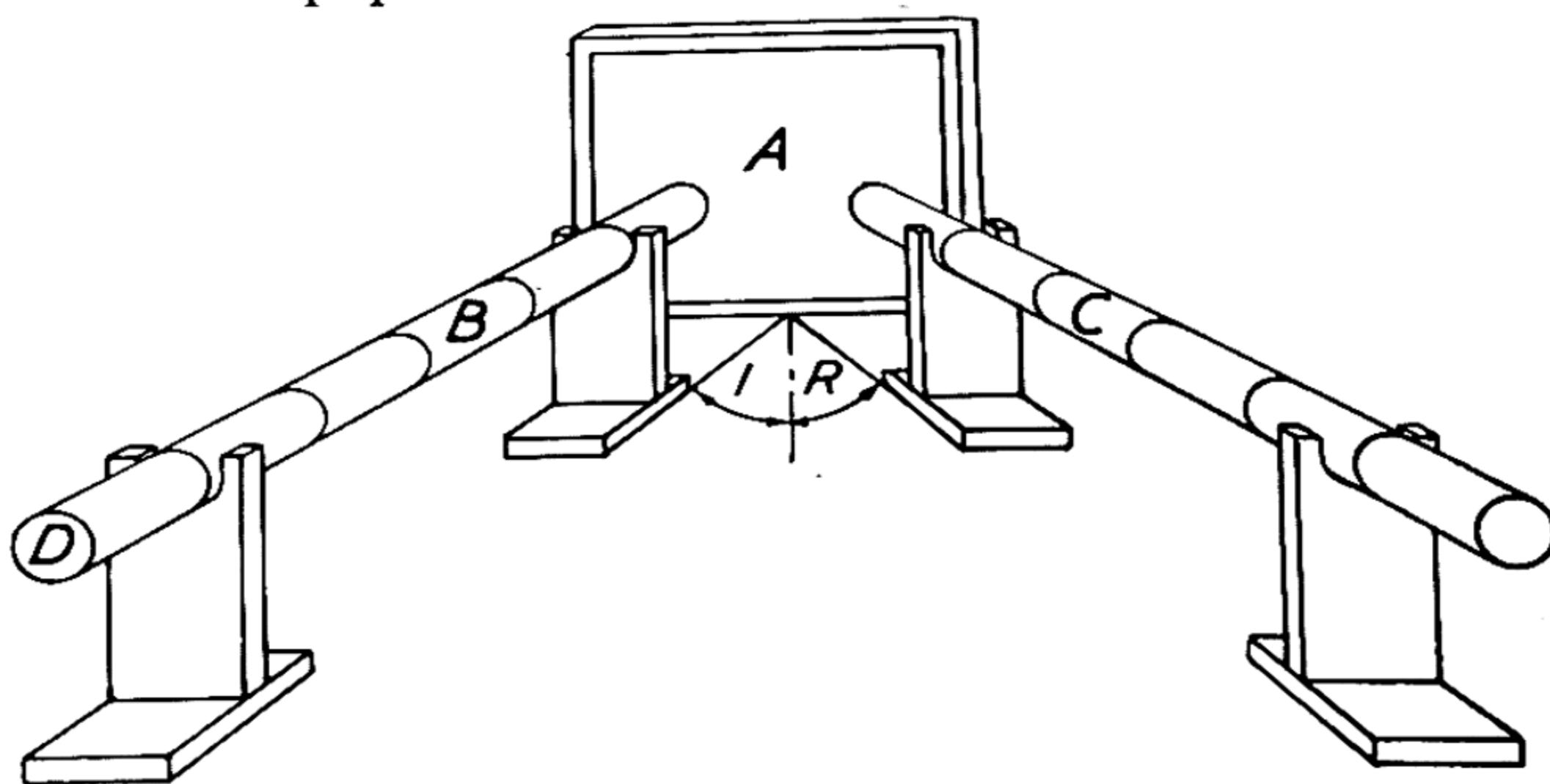


FIG. 56 (a). REFLECTION OF RADIANT HEAT

The low conductivity of cork and indiarubber can be demonstrated by placing pieces of these materials on an electric hotplate, or on a piece of sheet iron or brass placed on a tripod over a small Bunsen flame. The upper surfaces of the cork and rubber can be touched when they have been on the plate for some time, whereas a piece of metal of the same thickness soon becomes too hot to touch.

The low conductivity of liquids can be demonstrated by placing a piece of ice, weighted with a length of iron wire, in a test-tube containing the liquid, which can be boiled in the upper part of the tube by holding in a Bunsen flame. The ice does not disappear for a long time.

Boiling water can be poured into a thick glass jam-jar and into a thin glass beaker, placed in a tray, to show that a thick glass vessel cracks.

Why the Glass is silvered in a Vacuum Flask

The reflection of radiant heat by the silvered glass surfaces of a vacuum flask can be shown by using the apparatus in Fig. 56 (a).

A is a mirror which is supported in a vertical position by two wooden feet. *B* and *C* are tin-plate tubes about two feet long and three inches in diameter. These tubes can be made in the metal-work room. Satisfactory tubes can also be made by joining together empty cocoa-tins with their bottoms removed. The tins can be soldered together, or quite good joints can be made by wrapping with insulating tape.

The tubes are supported on wooden stands.

A source of radiant heat should be placed near the end *D* of the tube *B*. Two suitable sources of radiant heat are illustrated.

In Fig. 56 (*b*), *A* is a reflector from a motor-car wing-lamp. These can usually be obtained, second hand, from garages for a few pence. The reflector should be complete with lamp-holder, and it is supported on a wooden stand. It may be necessary to solder a piece of brass to the lamp-holder to fix the reflector to the wooden stand.

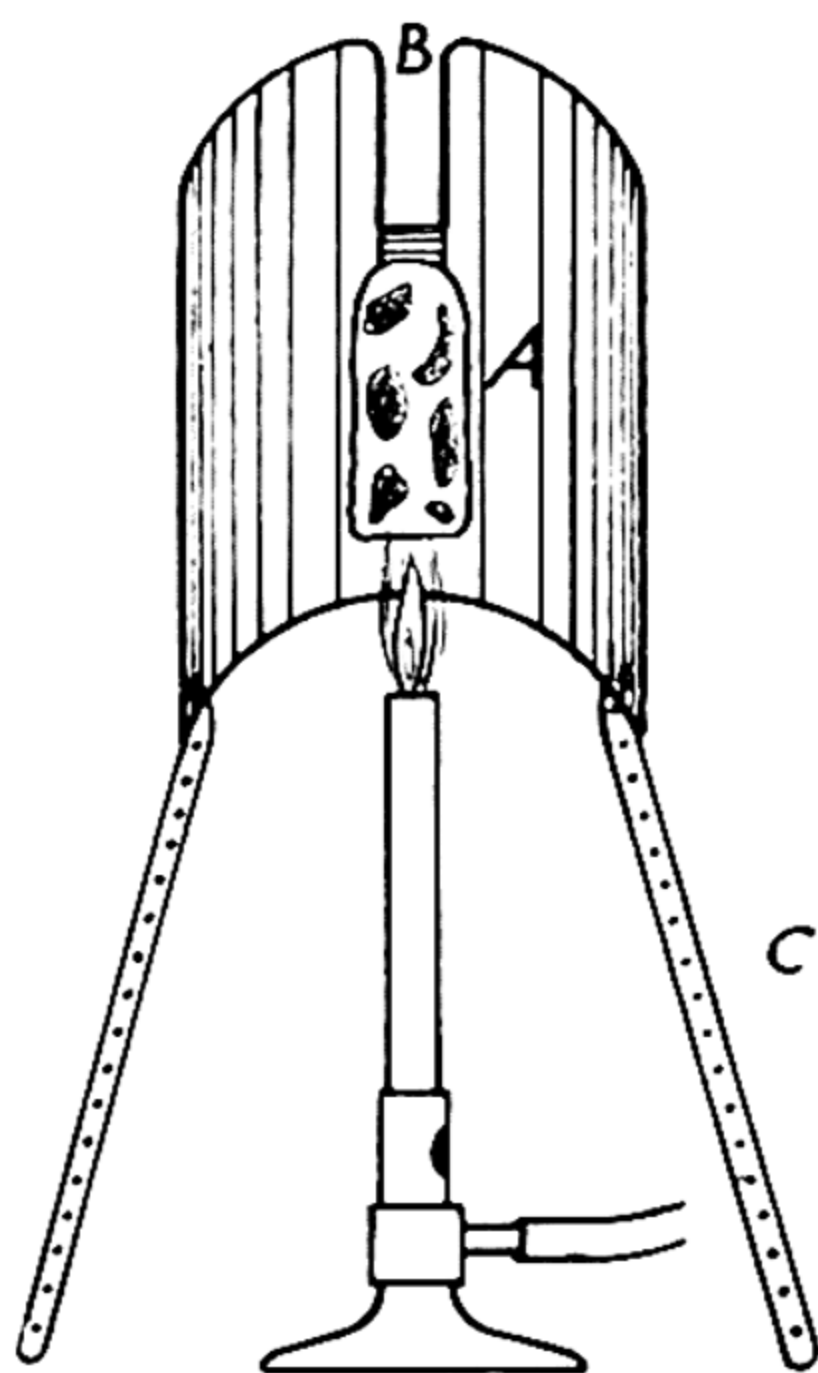


FIG. 56 (*c*). REFLECTION OF RADIANT HEAT

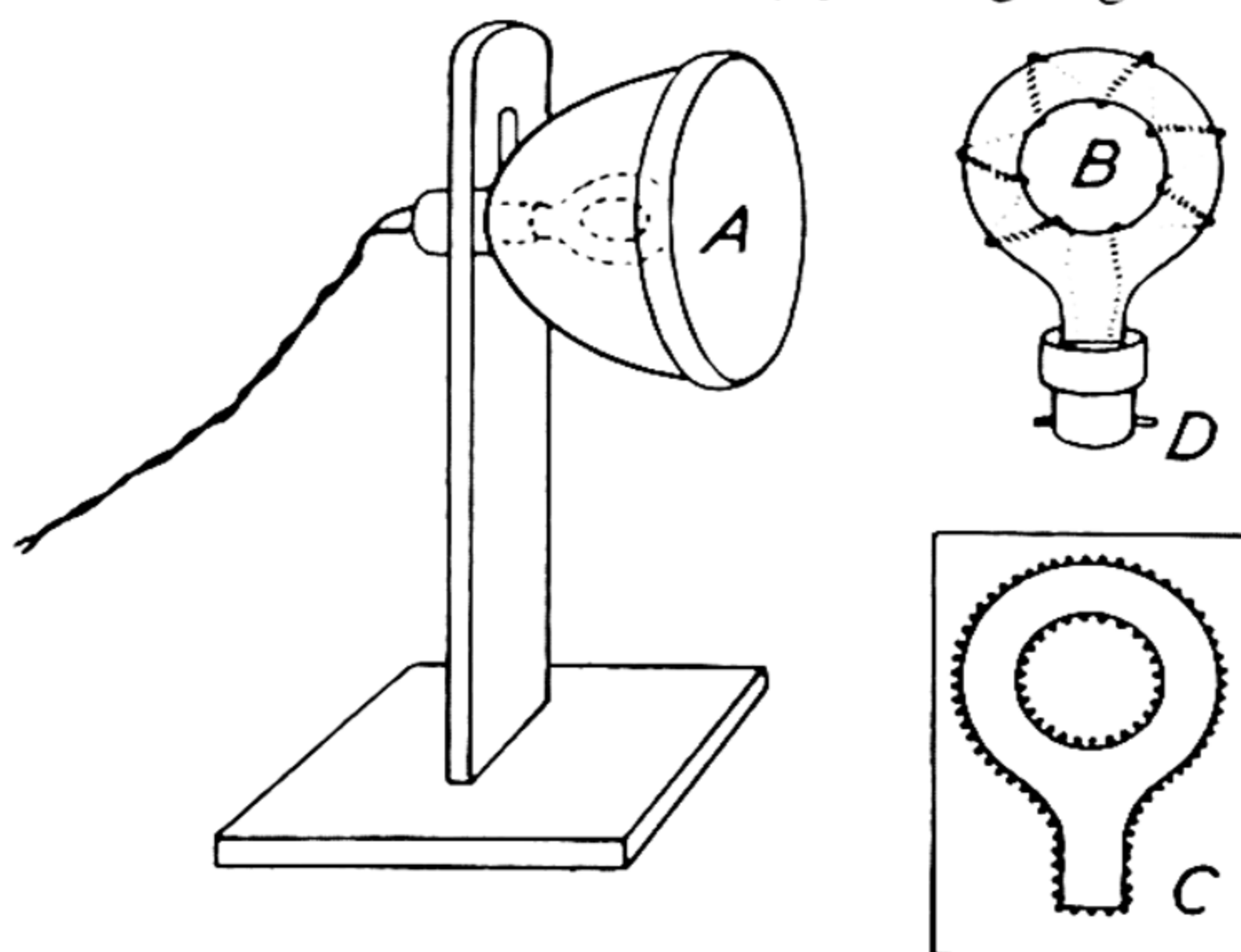


FIG. 56 (*b*). REFLECTION OF RADIANT HEAT

The heating element, *B*, is made by wrapping a nichrome wire spiral round a former made of uralite. The shape of the former should be traced out in pencil on a small piece of uralite, and holes should be drilled round the lines as illustrated in sketch *C*. The inner circle should be drilled out first. The former can be cleaned up with a file and should be about the size of a 12-volt lamp when completed.

D is the brass cap from a 6-volt or 12-volt lamp which is no longer any use. In breaking away the glass from the cap considerable care must be taken not to damage the leading-in wires, as the ends

of the nichrome wire must be joined to these by twisting the ends together.

The uralite is fixed into the brass cap with a little putty or the cement used for repairing fireplaces.

An electric heater made in this way will send radiant heat along the tube *B*. If the tubes are arranged so that the angle *I* is equal to the angle *R* the radiant heat will be reflected by the mirror along the tube *C*.

Fig. 56 (c) illustrates another suitable radiant heat source. *A* is a curved piece of tin-plate supported on three lengths of Meccano strip acting as legs. A strip of the tin-plate is cut down at *B*, and this supports a piece of gas-fire radiant. A lighted Bunsen burner placed under this piece of radiant soon makes it incandescent, and the curved tin-plate acts as a reflector of the radiant heat.

The reflected radiant heat can be detected at the end of the tube *C* by using a thermometer, the bulb of which should be painted with a solution of lamp-black in shellac, or by using a thermoscope.

A Simple Thermoscope

An excellent thermoscope can be made by using two small flasks and a length of narrow-bore glass tubing as illustrated.

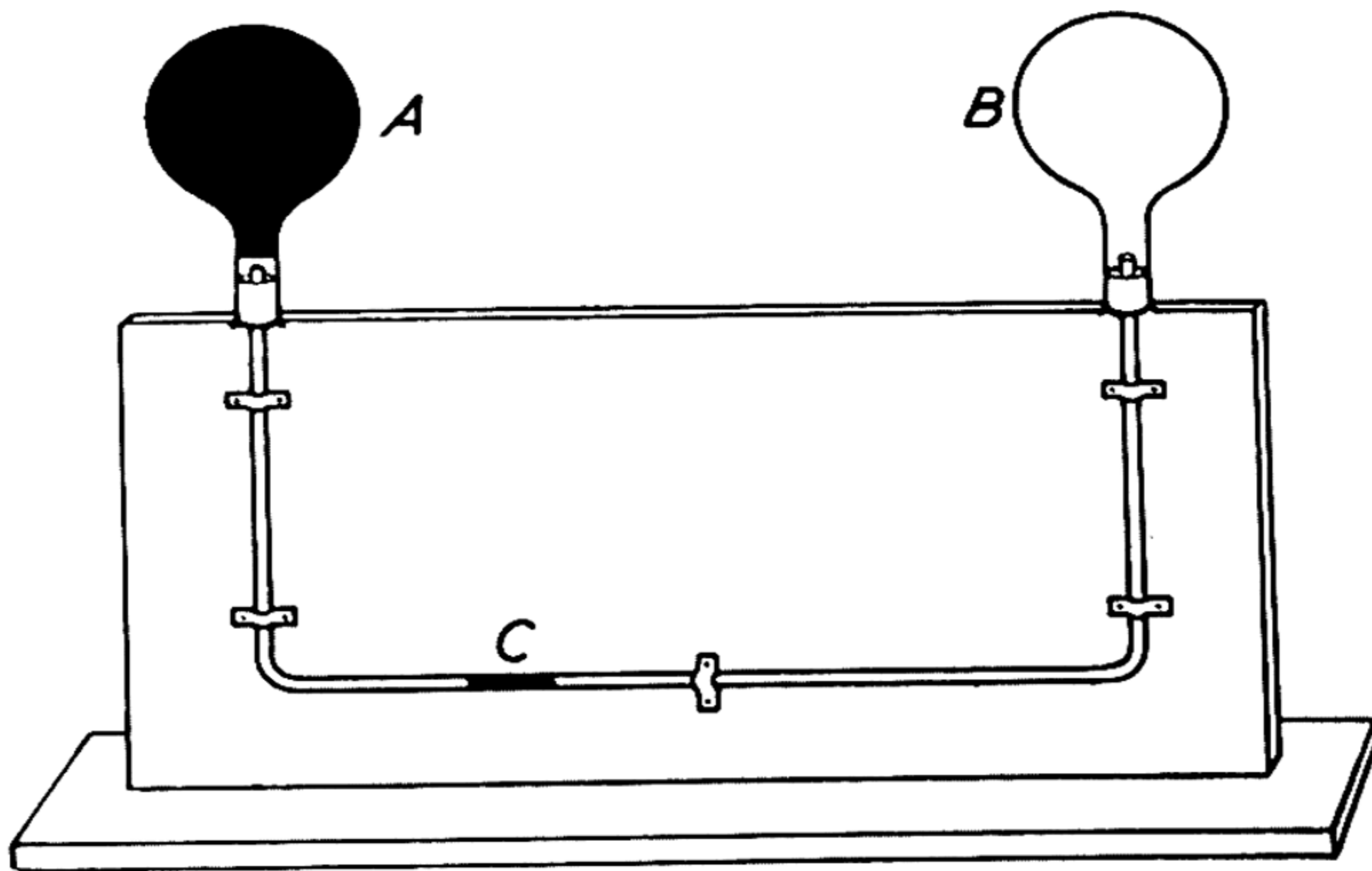


FIG. 57. THERMOSCOPE

A and *B* are 250-c.c. flasks. *A* is painted dead-black on the outside with a solution of lamp-black in bleached shellac. A U-shaped length of narrow-bore glass tubing is joined to the flasks by means of rubber bungs. *C* is a little mercury. The flasks and glass tubing are

fixed to the upright board by means of clips made from pieces of lead taken from lead-covered electric cable.

When the flask *A* is placed at the end of the tube *C*, in the reflection of radiant-heat apparatus described above, the heat is absorbed quickly by the dead-black surface of the flask, the air inside the flask expands, and the mercury moves to the right.

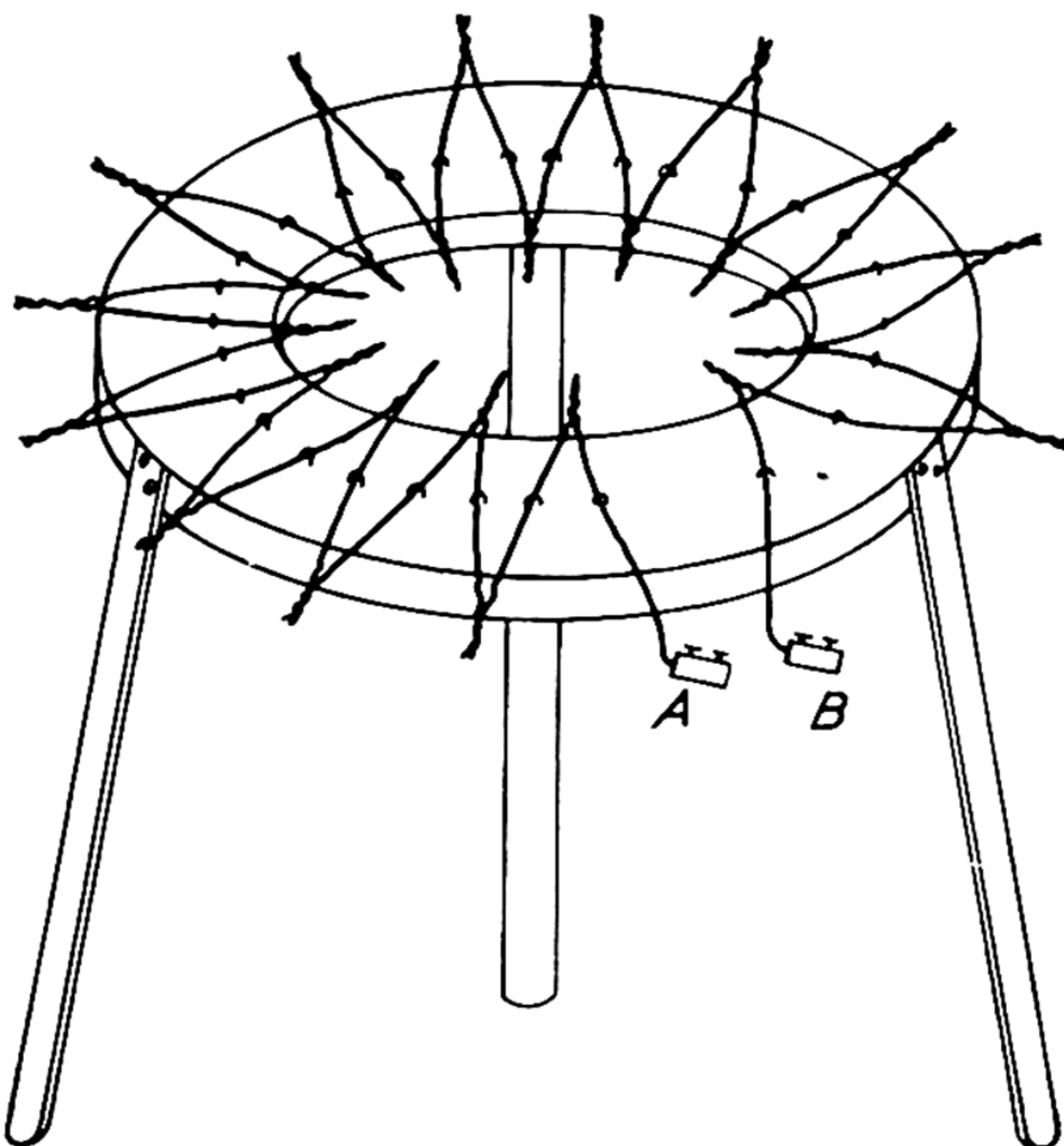


FIG. 58. APPARATUS TO SHOW THE PRINCIPLE OF THE THERMOPILE

The heat reflected along the tube *C* can also be detected immediately by means of a home-made thermopile described later in this section.

Thermopiles for detecting Radiant Heat

The principle of the thermopile can be shown with the apparatus illustrated in Fig. 58.

It consists of pieces of iron and copper wire arranged alternately, twisted together at the ends, and fixed to a wooden ring on a stand. The copper wire *A* and the iron wire *B* are connected to a sensitive galvanometer, a Bunsen flame is concentrated on the inner copper-iron junctions, and the resulting electric current produced gives a deflection of the galvanometer needle.

A most sensitive thermopile, which will give a considerable galvanometer deflection when the heat radiated from the hand is allowed to fall on it, is illustrated in Fig. 59.

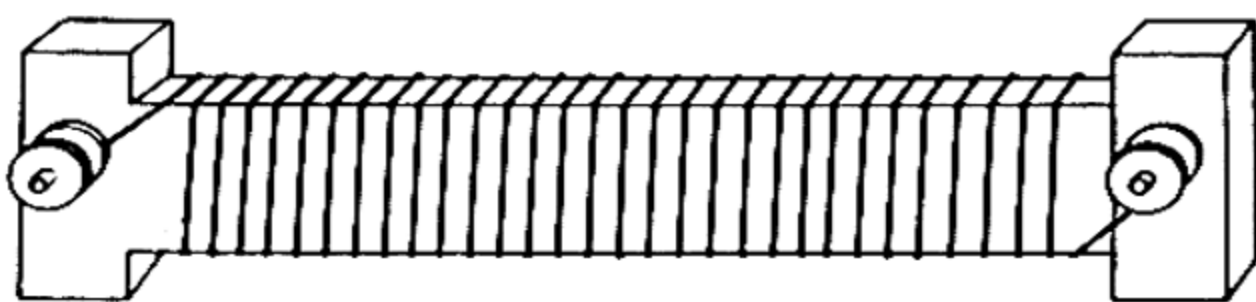


FIG. 59. A SENSITIVE THERMOPILE

It consists of about a hundred turns of bare Eureka wire, No. 32, wrapped on a uralite or ebonite former about 5 in. long and 1 in. wide. The ends of the wire are fixed to the terminals fitted into holes drilled at each end of the former. One half of each turn

is copper-plated by half immersing the former in copper-sulphate solution. A very weak current should be used when plating, and this should be allowed to pass for about ten minutes. A flash-lamp battery will supply an adequate current, and the circuit is shown in Fig. 61.

In this way about a hundred thermocouples are made on each face of the thermopile. The terminals are connected to the terminals of a sensitive galvanometer.

To show that Heat Radiation travels in Straight Lines

A is the source of radiant heat already described. *B* is a piece of polished brass plate suspended by means of a wire from a retort stand, and *C*

It consists of about a hundred turns of bare Eureka wire, No. 32, wrapped on a uralite or ebonite former about 5 in. long and 1 in. wide. The ends of the wire are fixed to the terminals fitted into holes drilled at each end of the former. One half of each turn

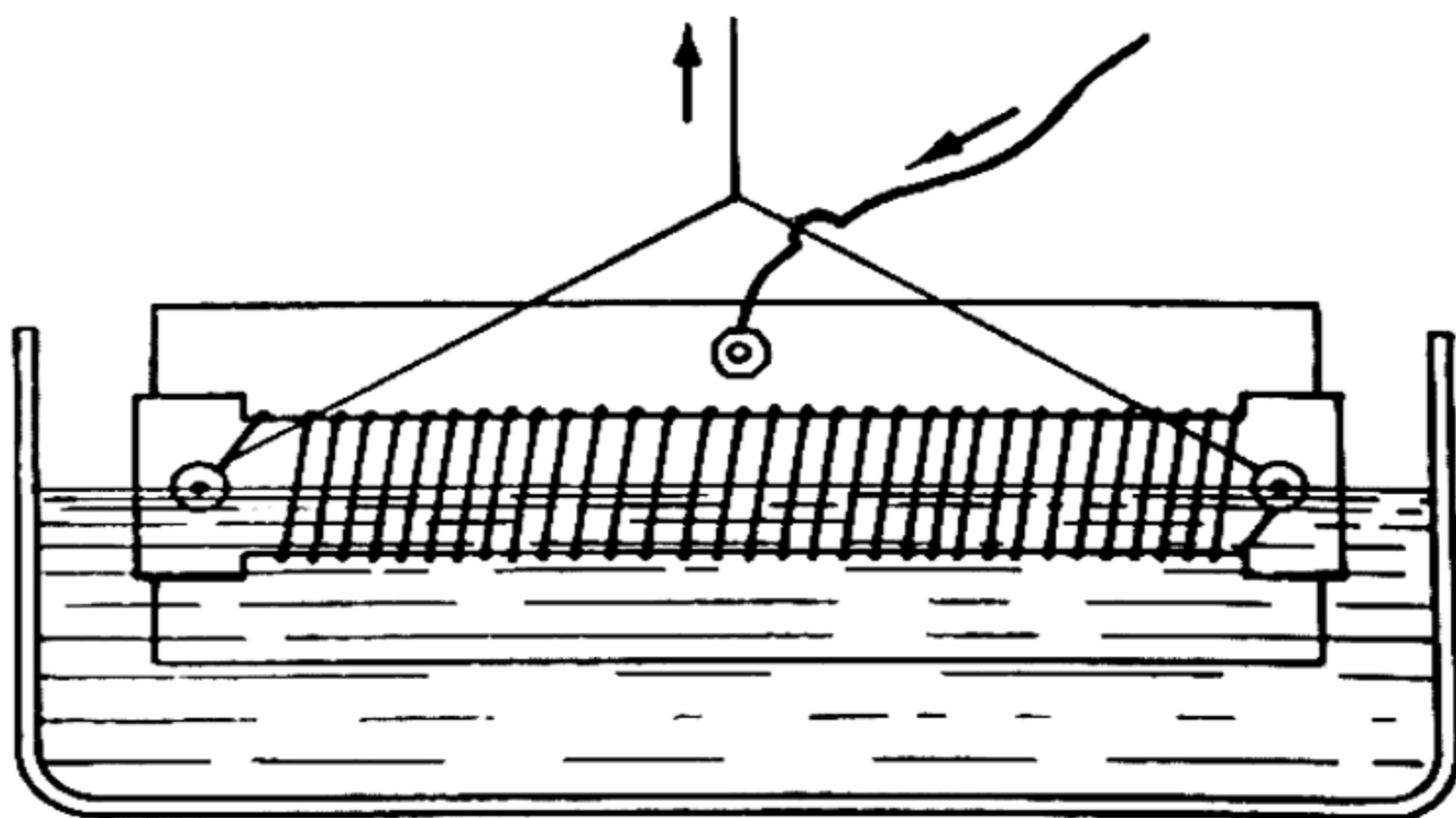


FIG. 60. COPPER-PLATING THE EUREKA WIRE

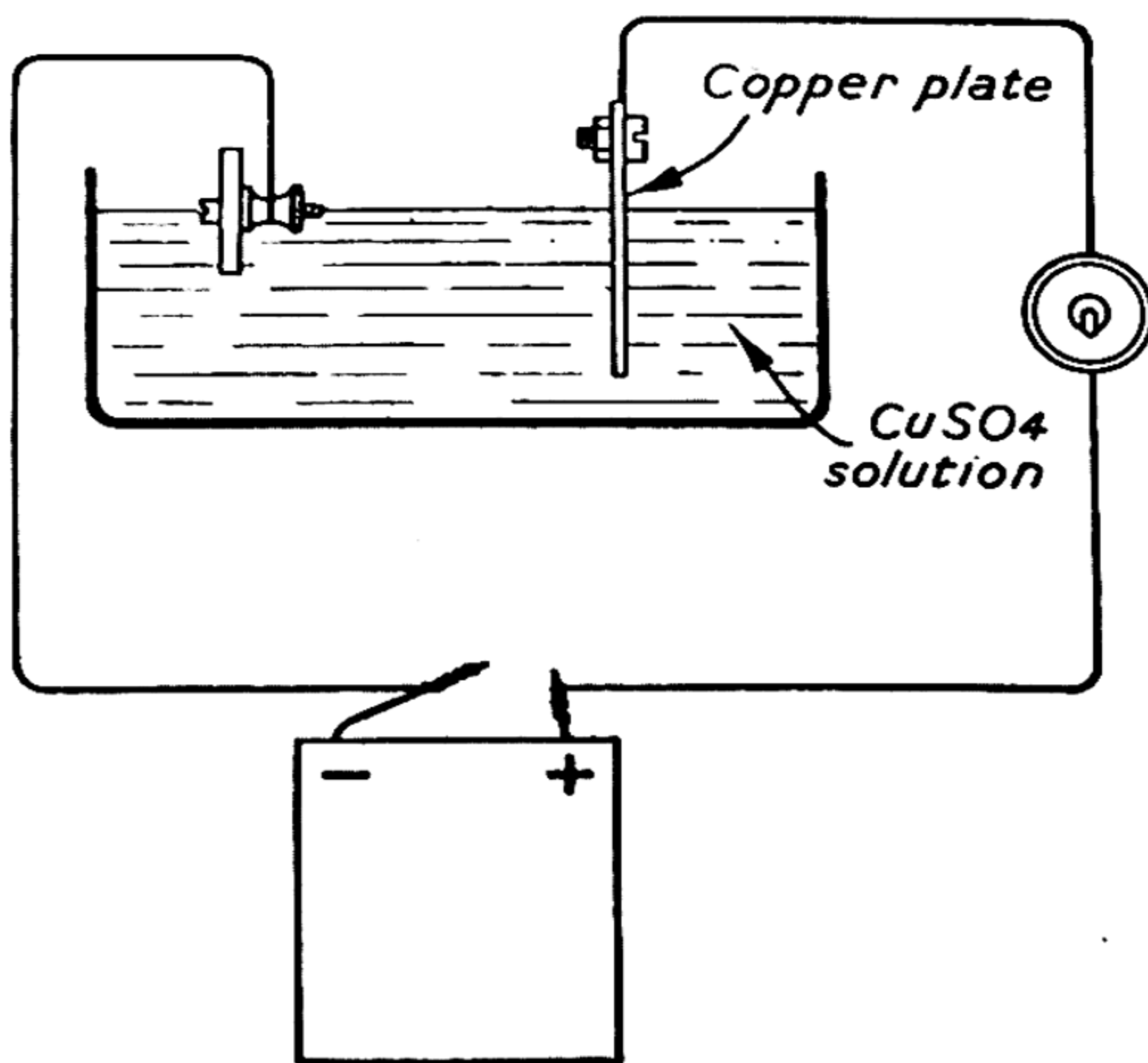


FIG. 61. COPPER-PLATING CIRCUIT

is a piece of heat-sensitive paper stuck to a piece of plywood on a stand.

In a short time a heat shadow of the same shape as the metal *B* will be seen on the screen.

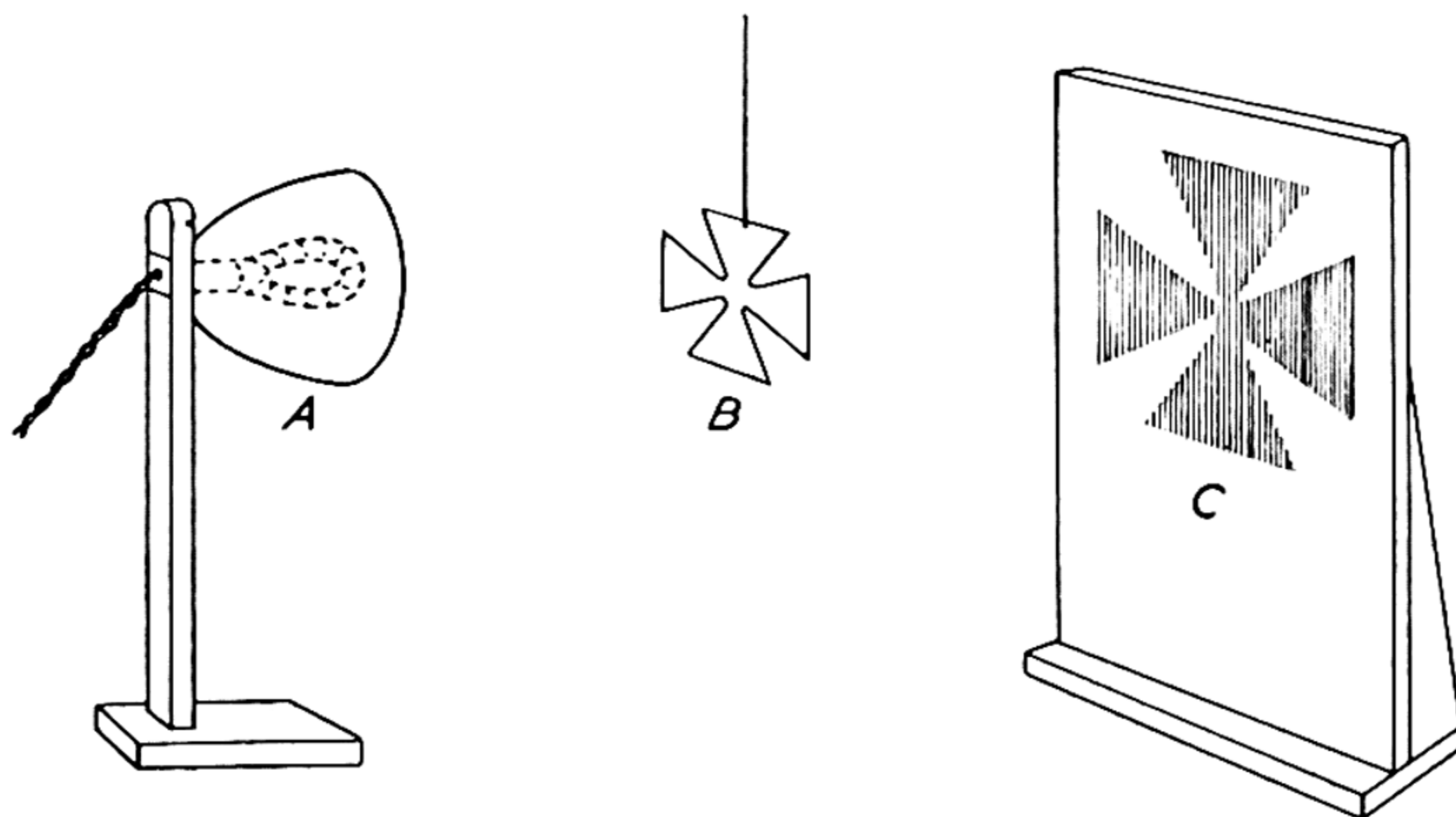


FIG. 62. DEMONSTRATING THE STRAIGHT LINES OF HEAT RADIATION

Heat Radiation does not heat the Air through which it passes

In Fig. 63 *A* is the source of radiant heat and *B* is a thermometer with a blackened bulb (lamp-black in bleached shellac) held a short distance below. An ether thermoscope, a Crooke's Radiometer, or a thermopile can be used instead of the thermometer. In a very short time the thermometer or thermoscope will register an appreciable rise of temperature, the radiometer vanes will revolve rapidly, or the thermopile will give a considerable deflection of a galvanometer needle.

If the thermometer bulb, thermoscope, radiometer, or thermopile is screened with a

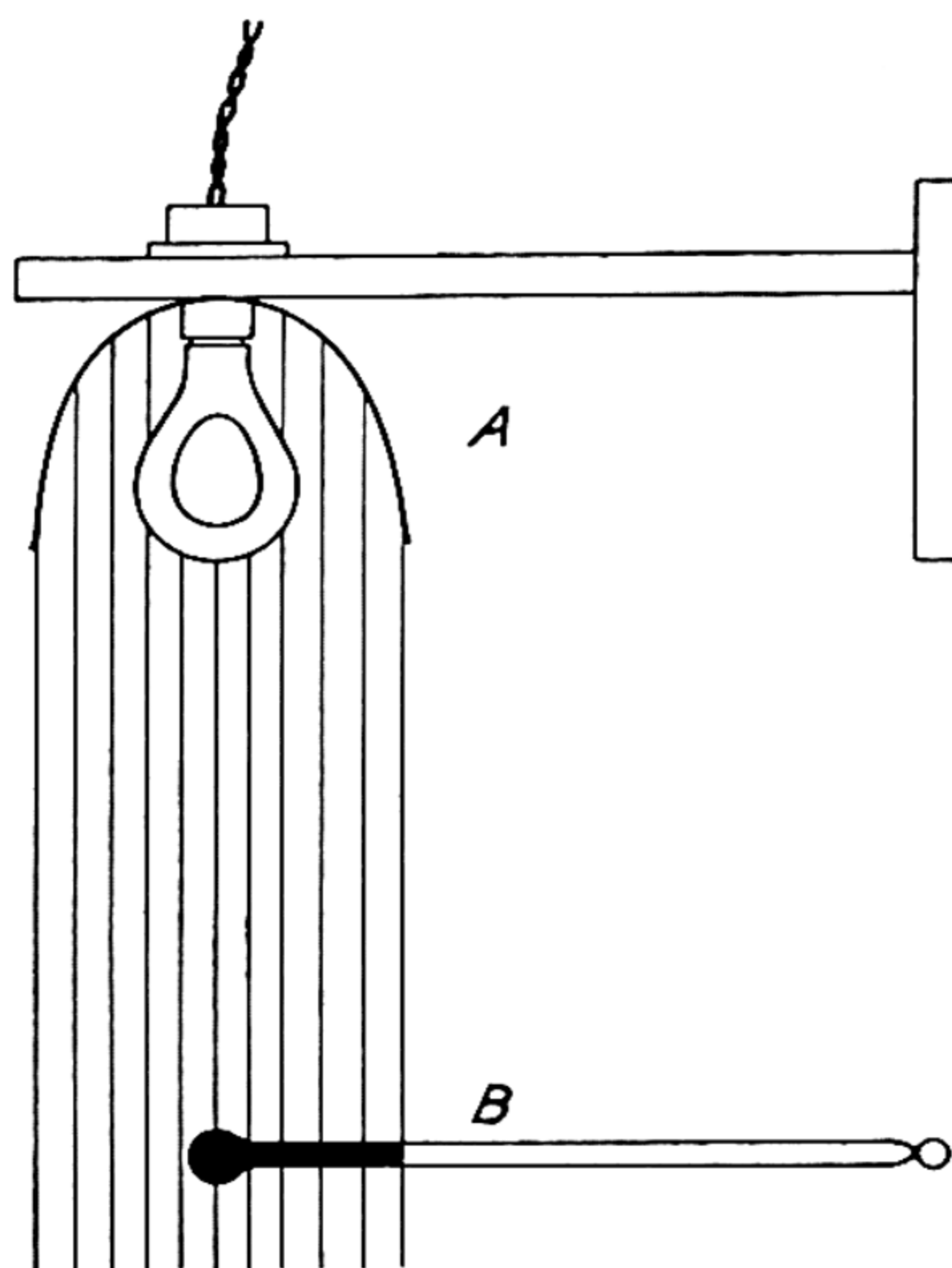


FIG. 63. DEMONSTRATING THAT HEAT RADIATION DOES NOT HEAT THE AIR THROUGH WHICH IT PASSES

piece of card from the radiation the level of the mercury or ether will fall, the radiometer vanes will cease revolving, or the thermopile will give no deflection, showing that the air around is not heated at all.

To show that a Dead-black Surface emits Thermal Radiations better than a Polished Surface

A is a cubical tin box and *B* and *C* are 250-c.c. flasks painted on the outside with a solution of lamp-black in bleached shellac. The

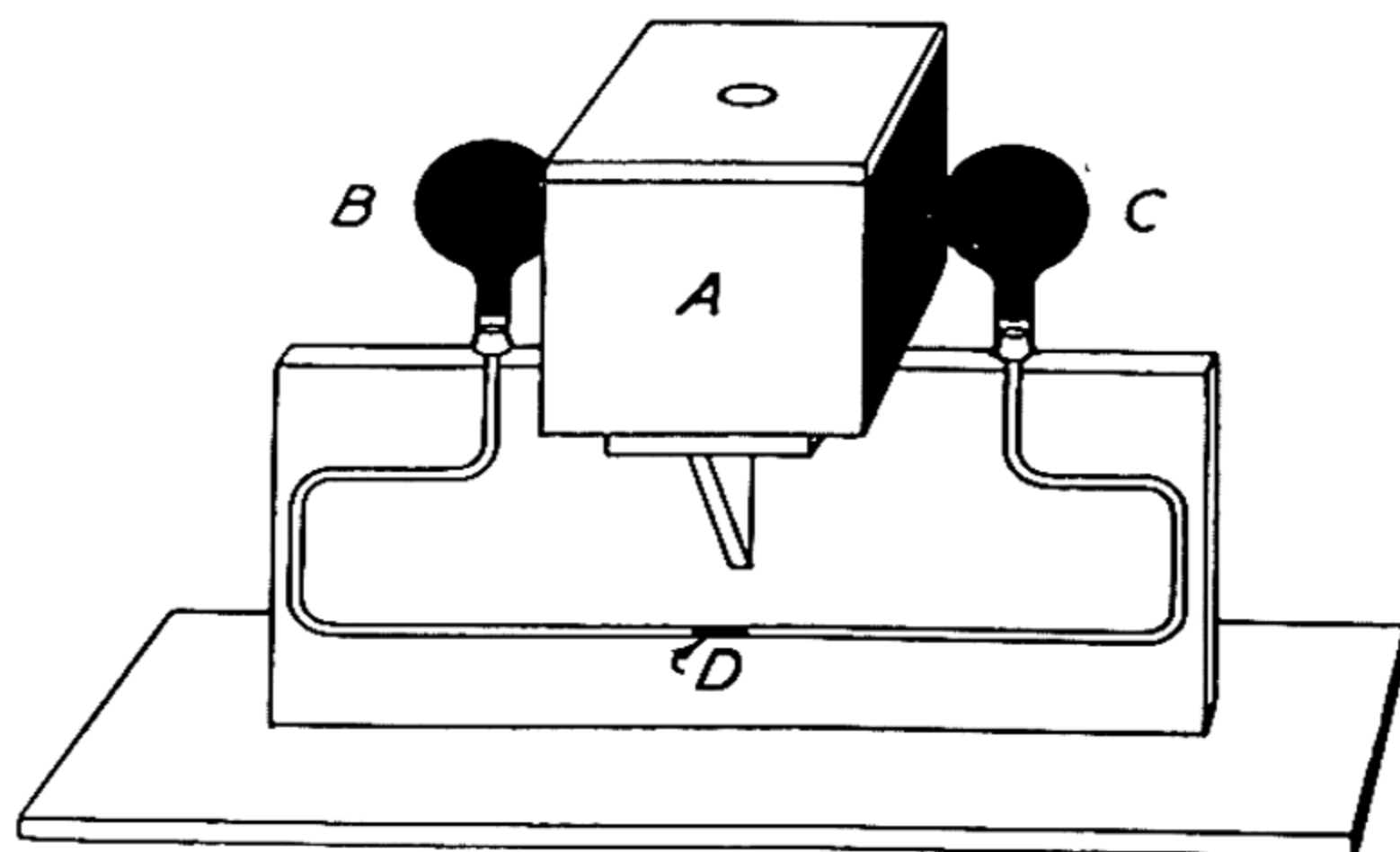


FIG. 64. TO SHOW HOW A BLACK SURFACE EMITS HEAT

face of the tin box opposite the flask *C* is painted dead-black with the lamp-black solution, and the face of the box opposite the flask *B* is highly polished with metal polish.

Boiling water is poured into the tin box through the hole in the lid, and the mercury thread, *D*, in the narrow-bore glass tubing moves to the left.

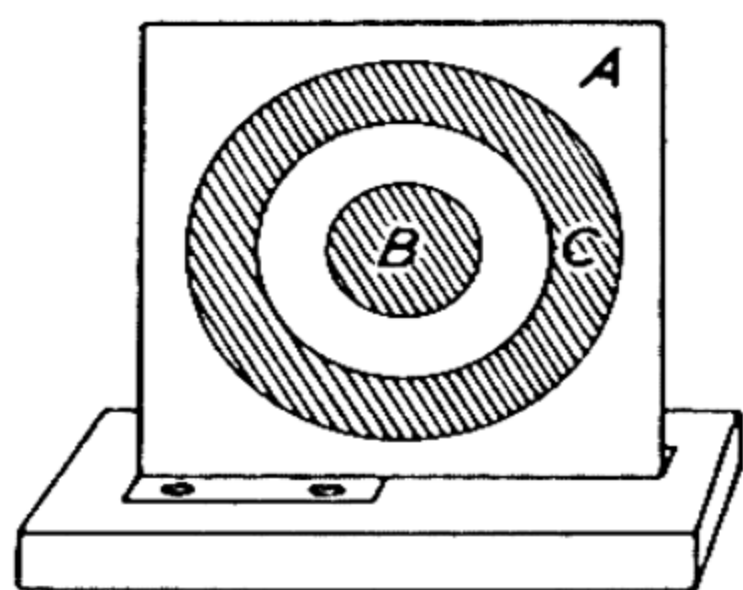


FIG. 65. TO SHOW DIFFERENCE IN REACTION TO THERMAL RADIATION OF POLISHED AND DEAD-BLACK SURFACES

Another Interesting Way of demonstrating that a Polished Surface reflects Thermal Radiations and a Dead-black Surface absorbs them

A is a piece of thin tin plate supported on a wooden stand. The circle *B* and ring *C* on the front surface are painted dead-black after the whole surface has been well polished. The whole of the back surface

is covered with a mixture of mercuric iodide and gum or paste.

A source of radiant heat is held in front of the tin plate, and the dead-black parts absorb the heat and the red mercuric iodide turns

yellow. Where the heat is reflected by the polished tin the mercuric iodide remains red.

Apparatus to demonstrate the Reflection of Radiant Heat by Parabolic Reflectors

A and *B* are reflectors from motor-car headlamps. Suitable second-hand reflectors can usually be obtained from large garages for a few shillings.

They should be fixed to wooden stands, and an electric heating element should be made to fit into the reflector *A* as previously described. Reflector *B* should be placed about two yards away from reflector *A*, so as to receive the parallel heat rays sent out by *A*.

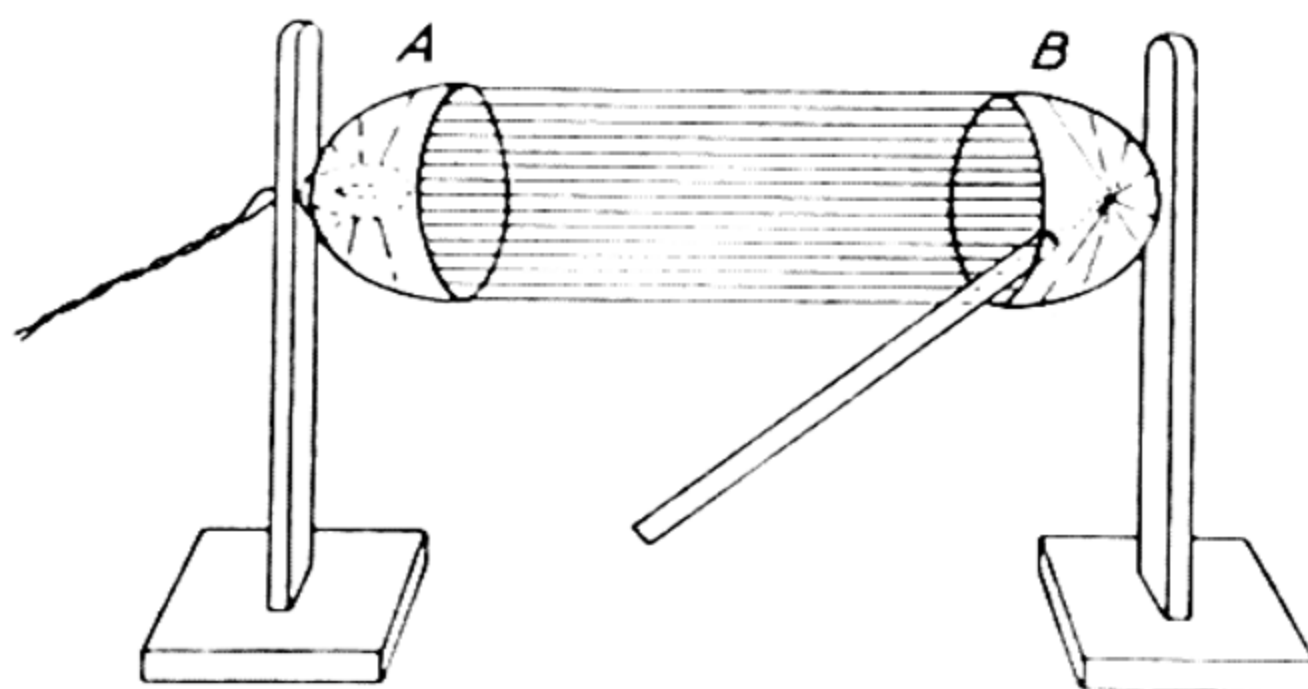


FIG. 66. REFLECTION OF HEAT BY PARABOLIC REFLECTORS

These parallel heat rays are focused by the reflector *B* on to a match held in a hole made in the end of a length of dowelling. The match bursts into flame.

A Reflection Heater for Use with a Gas or Electric Fire

The three upright pieces of wood *A*, *B*, and *C*, each about 10 in. by 7 in. by $\frac{1}{2}$ in., are held together by the wooden back *D* and the piece of wood *E*. The piece *D* should be about 10 in. by 14 in.

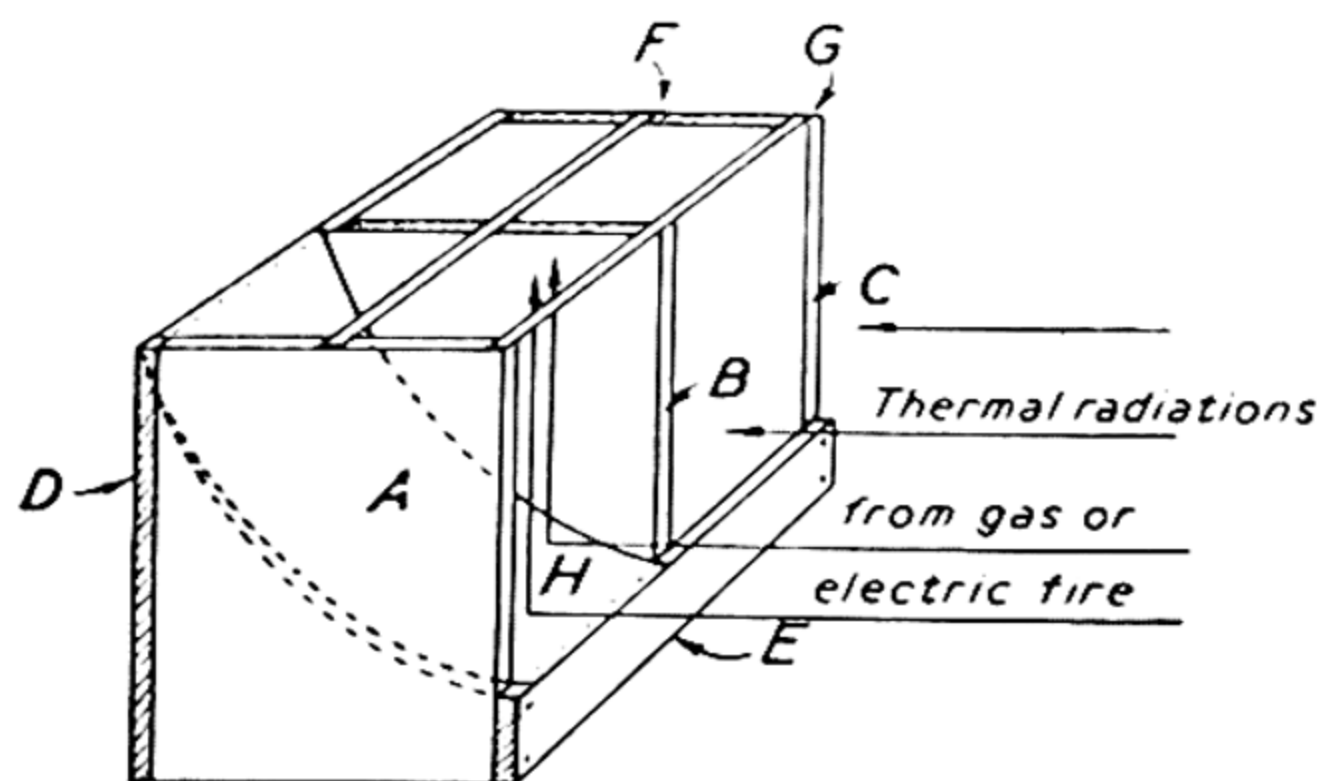


FIG. 67. REFLECTION HEATER

F and *G* are pieces of strip brass or strip iron.

H is a piece of highly polished tin-plate or, better still, stainless steel.

Shallow tin troughs containing water are placed above the reflector *H*, and above the space without the reflector.

The apparatus is then placed in front of a gas or electric fire, and the rise of temperature of the water in the two tins is noted.

Apparatus for comparing Heat Conductivities of Brass and Wood

The apparatus is made from a piece of wood $\frac{1}{2}$ in. thick. Brass screws $\frac{5}{8}$ in. long are fixed as in the illustration. The pointed ends of the screws should be filed level with the face of the wood. A piece

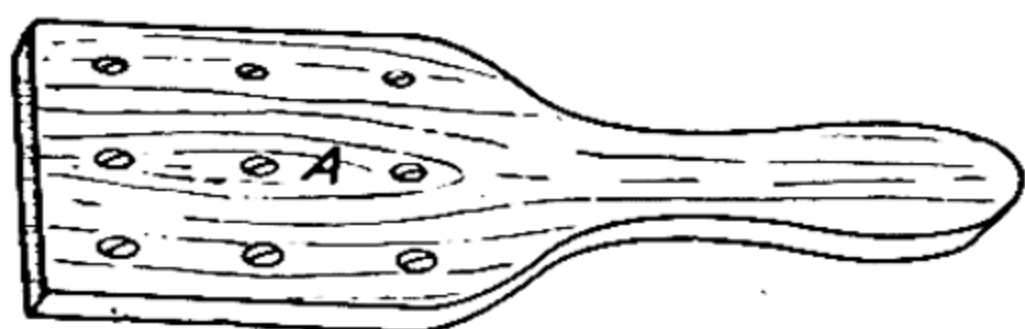


FIG. 68. TO COMPARE BRASS AND WOOD AS CONDUCTORS OF HEAT

of white paper should be pasted over the heads of the screws and the face *A* of the wood. A piece of filter-paper, saturated with a solution of cobalt nitrate and afterwards dried by suspending in warm air, should be pasted over the ends of the screws and the opposite face of the wood.

The apparatus should then be held near to a piece of gas-fire radiant supported above a Bunsen burner with the face *A* towards the radiant. The white paper will char where it is in contact with the wood, and the filter-paper will turn blue where it is in contact with the ends of the screws.

Apparatus for comparing Heat Conductivities of Metals

A, *B*, and *C* are iron, brass, and copper rods. A piece of brass plate is soldered to the end of each rod, and on each plate is placed a small piece of phosphorus.

A Model Davy Lamp

A, *A* are copper gauze cylinders each closed at one end. They are made from gauze with about 30 holes to the inch so that the

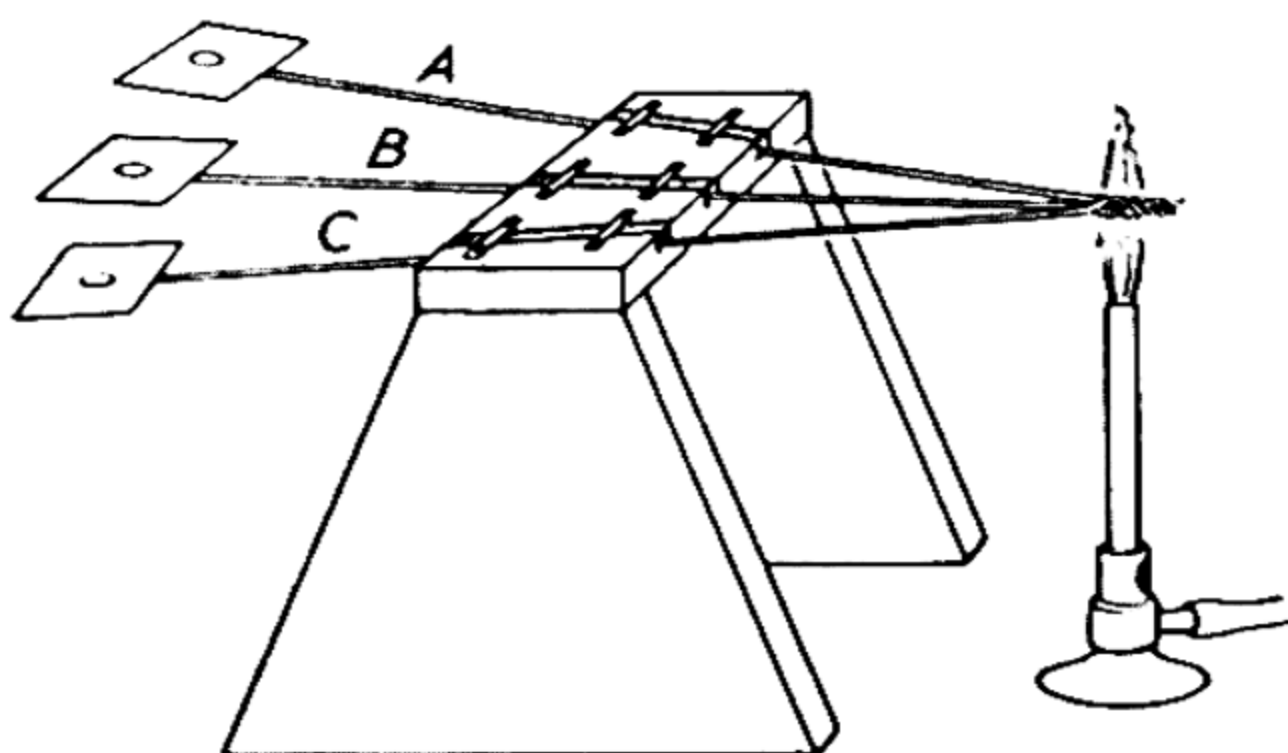


FIG. 69. TO COMPARE HEAT CONDUCTIVITY OF METALS

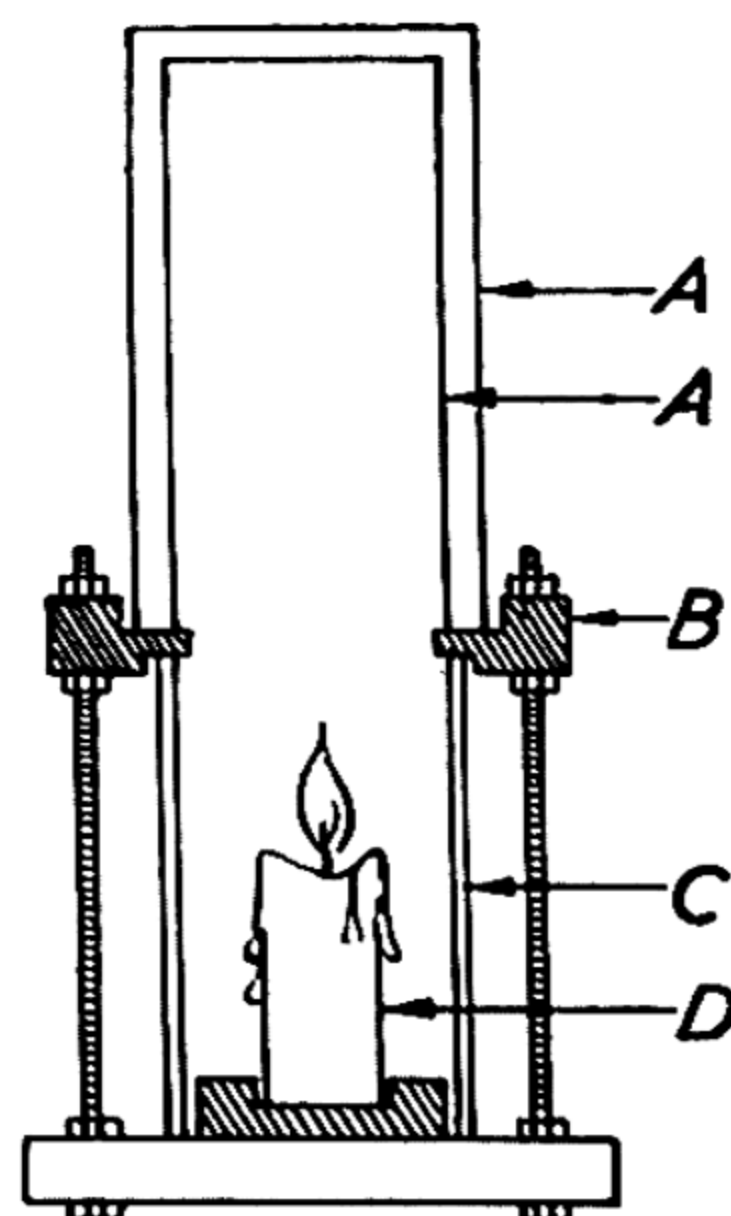


FIG. 70. THE DAVY LAMP

inner cylinder is about 5 in. high and about $1\frac{1}{2}$ in. in diameter. Each cylinder is closed with a copper gauze disc which is sewn in position with a needle and thin copper wire. The cylinders are made so as to

have about $\frac{1}{2}$ in. overlap, and the edges are folded over and hammered flat. The open ends of the gauze cylinders fit into a wooden ring, *B*, and the joint is sealed with putty or Plasticine. *C* is a short length of wide glass tubing (a piece of broken lamp-glass), and the wooden ring *B* and the wooden base are held together with Meccano screwed rods and nuts. *D* is a small oil lamp or candle. The gas from a Bunsen burner can be played on the outside of the cylinder while the lamp or candle is lighted. The coal-gas can be seen burning inside the gauze, but the burner is not ignited.

To show that Mercury is a Better Conductor of Heat than Water

A and *B* are large glass test-tubes, each about $1\frac{1}{4}$ in. in diameter. Round the outside of each is wrapped a layer of heat-sensitive paper. The tube *A* is filled with water, and the tube *B* is filled with mercury. The tubes *A* and *B* are each fitted with a layer of cork holding a smaller combustion-glass test-tube, the bottom of which reaches down into the water and mercury respectively.

A little methylated spirit is placed in each of the smaller tubes, and this is ignited. The heat-sensitive paper round *B* soon indicates that heat has travelled through the mercury.

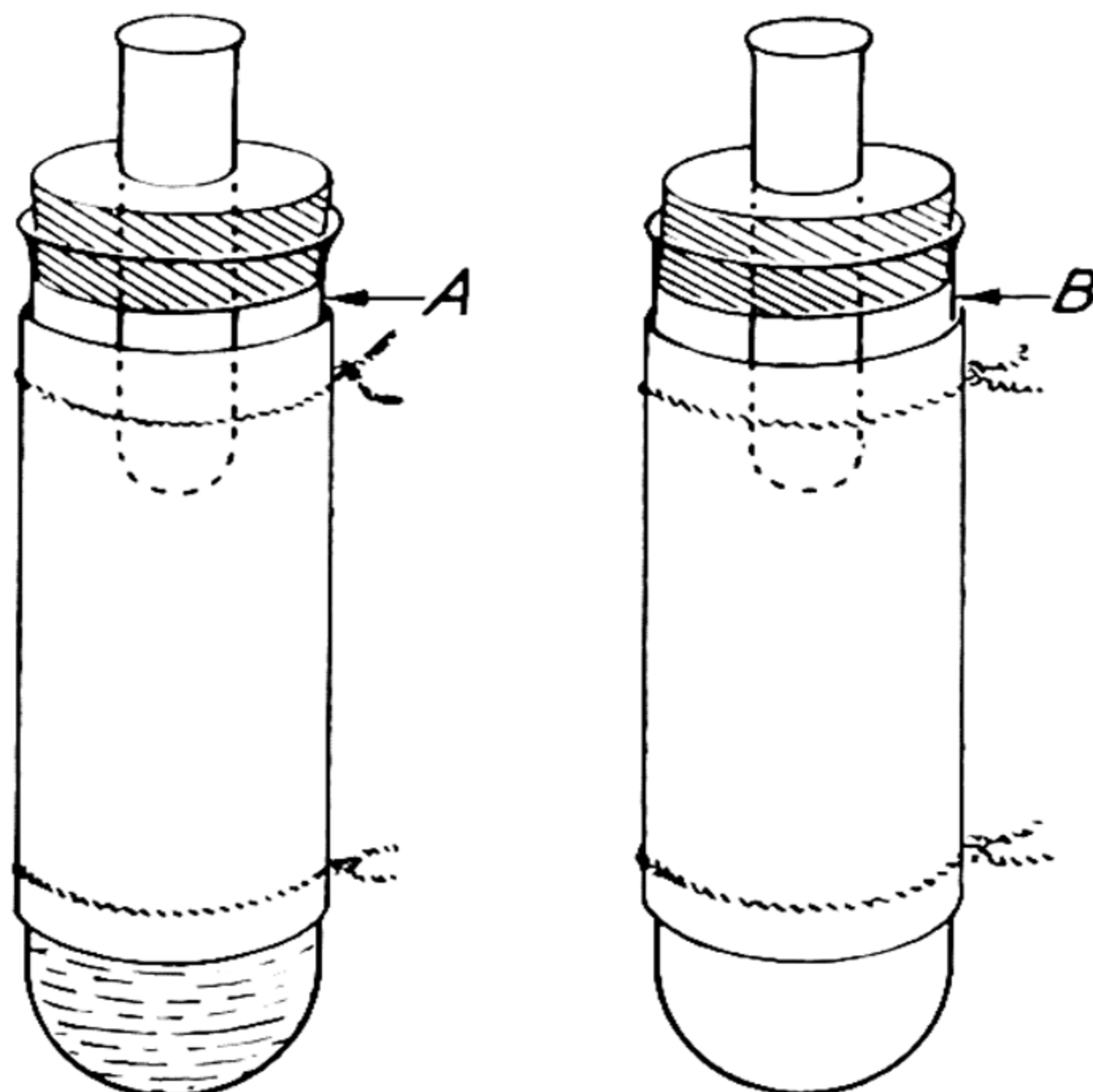


FIG. 71. COMPARING MERCURY AND WATER AS CONDUCTORS OF HEAT

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

BEAN, H. E.: *Everyday Science*, Book I.

BRAY, F.: *Elementary Science*, Part II.

FREWIN, J. G.: *A New Experimental Science*.

GUTHRIE, J. B.: *Elementary Science*, Part I.

Historical Apparatus ("Modern Science Memoirs," No. 8).

LOW, A. M.: *Popular Scientific Recreations*.

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School, Part II.*
 MACDOUGALL, A. T.: *Nature's Mystic Movements.*
 SCARR, W. A.: *Science in Common Things, Book I.*
 SPEAKMAN, C.: *Handwork Science, Book I.*

See also pp. 123–127 of *Everyday Science Topics, Book I.*

Film

Transference of Heat (16 mm., sound and silent, 3 reels) (British Gas Council).

Film-strips

Great Inventors and their Works (Visual Information Service).

Heat (Newton and Co., Ltd).

Science in Everyday Life—Heat, Conduction, Convection, Radiation (Army Kinema Corporation).

Thermometers (Common Ground, Ltd)..

(I) Water in the Home

The Density of Water is greatest at 4°C.

Fig. 72 shows a model of Hope's apparatus for demonstrating that the maximum density of water is at 4°C., used for illustrating why ponds freeze from the top downward.

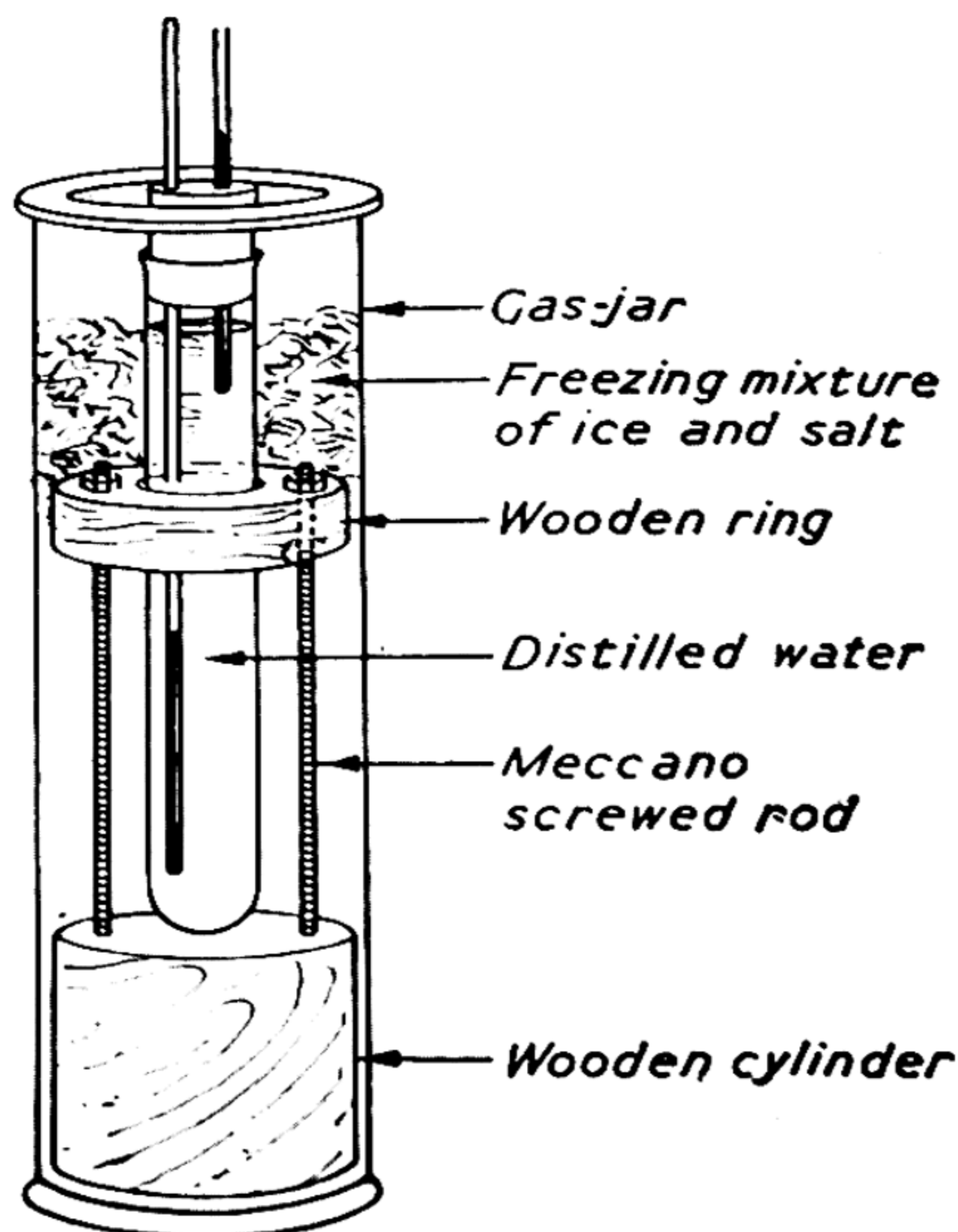


FIG. 72. MODEL OF HOPE'S APPARATUS

The Composition of Water

Apparatus for the analysis of water by means of an electric current is illustrated in Fig. 73. A little dilute sulphuric acid must be added

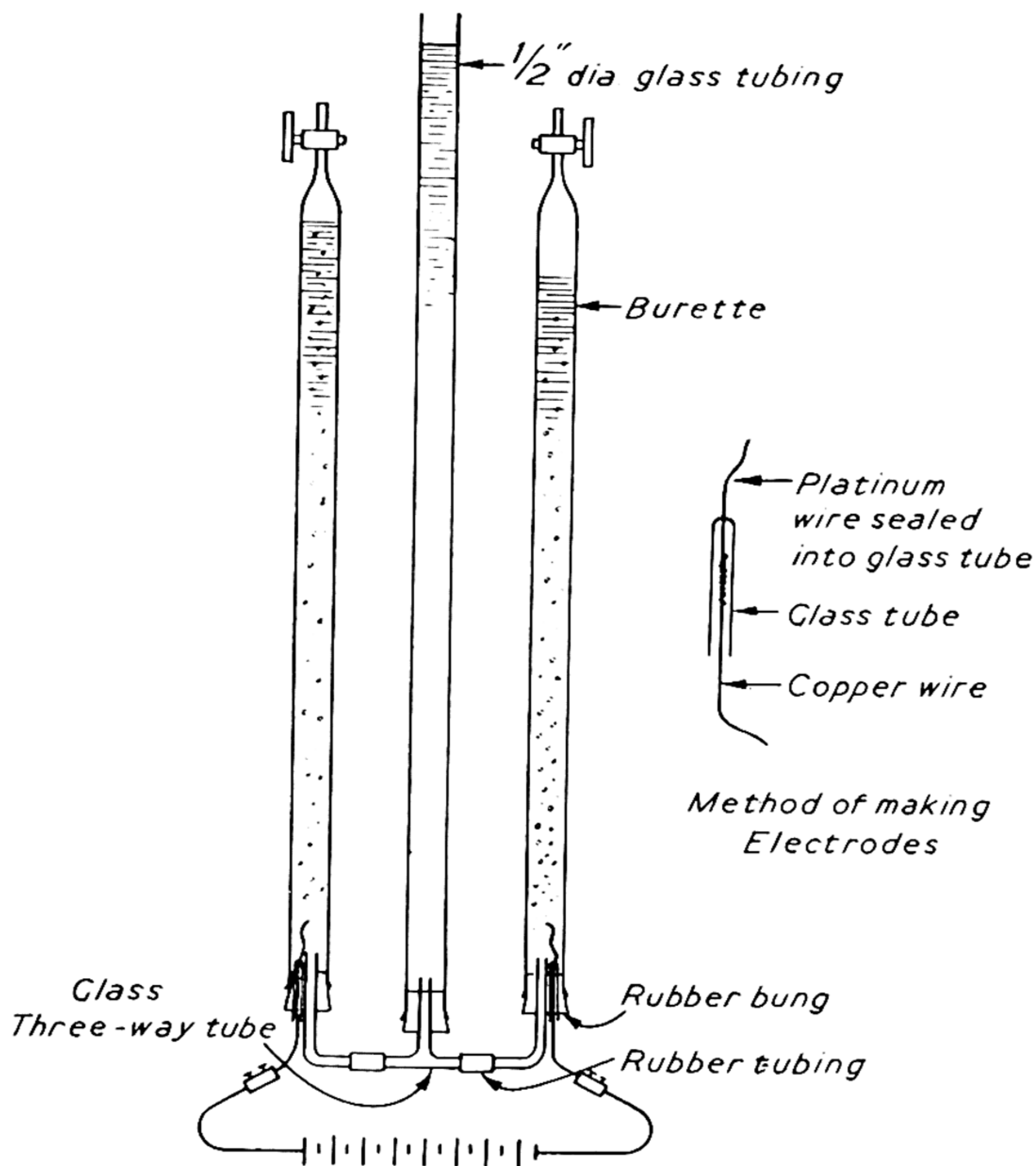


FIG. 73. ANALYSIS OF WATER BY AN ELECTRIC CURRENT

to the water. If it is desired to show the volume composition of water, carbon electrodes are not suitable. Short lengths of platinum wire or foil are necessary. At least 20 volts direct current is also required.

Projecting the Electrolysis of Water on to a Screen

The apparatus shown in Fig. 74 can be used with an optical lantern to project on to a screen the electrolysis of water. The special trough required is described at p. 223 in Chapter VI.

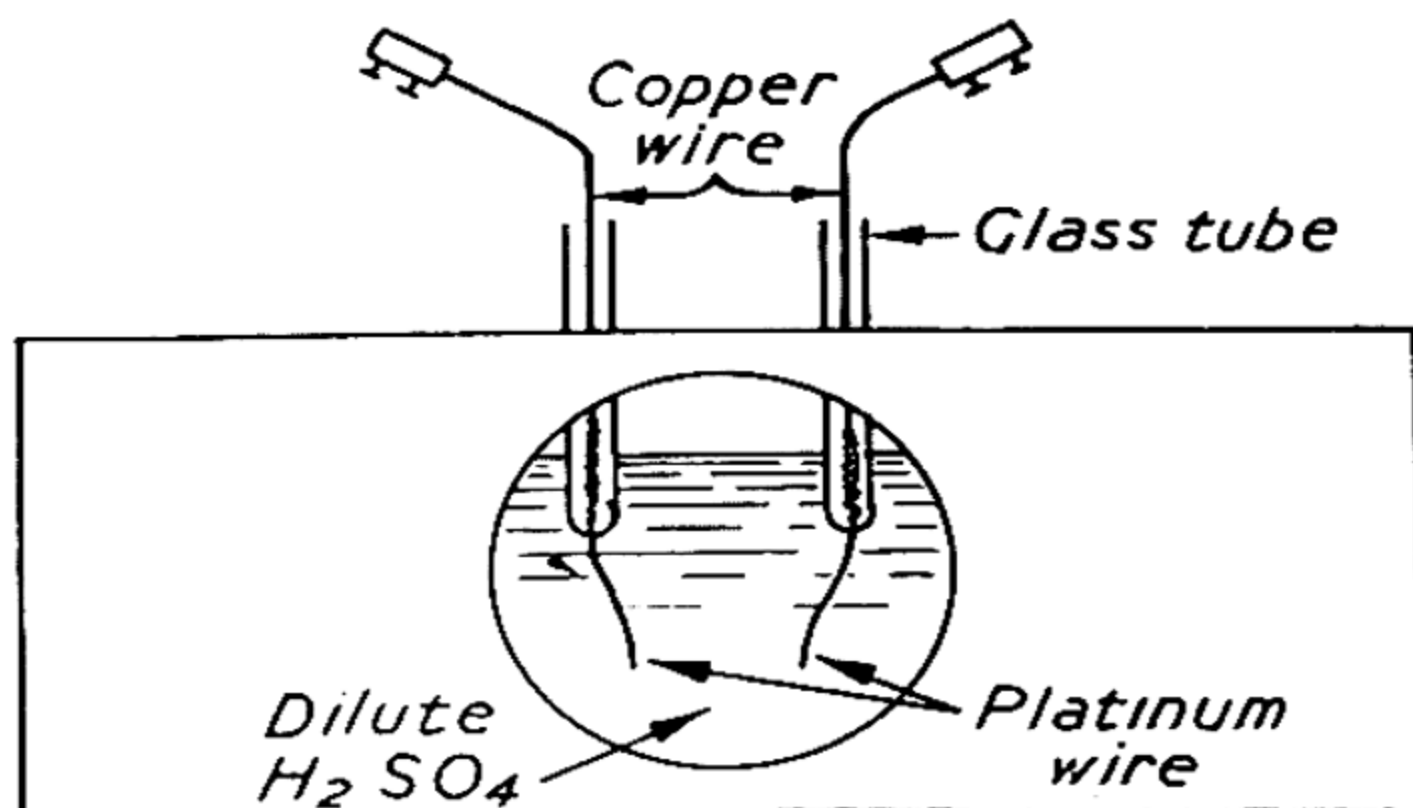


FIG. 74. PROJECTING THE ELECTROLYSIS OF WATER

The method of decomposing water by burning magnesium in the steam from boiling water, described in many text-books, is a

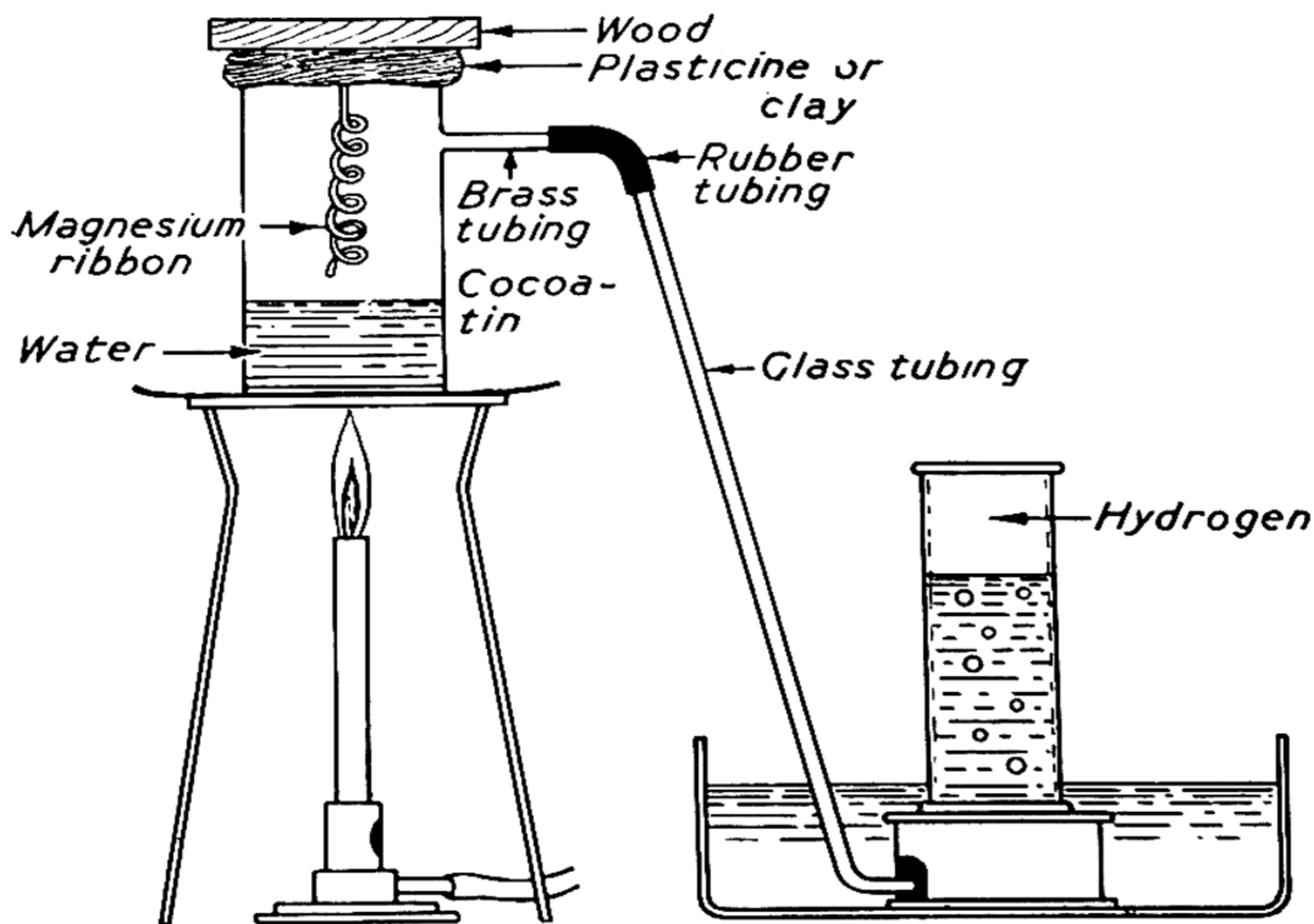


FIG. 75. APPARATUS FOR DECOMPOSING WATER

dangerous experiment. A much more satisfactory method is that due to Dr William Millar and illustrated in Fig. 75.

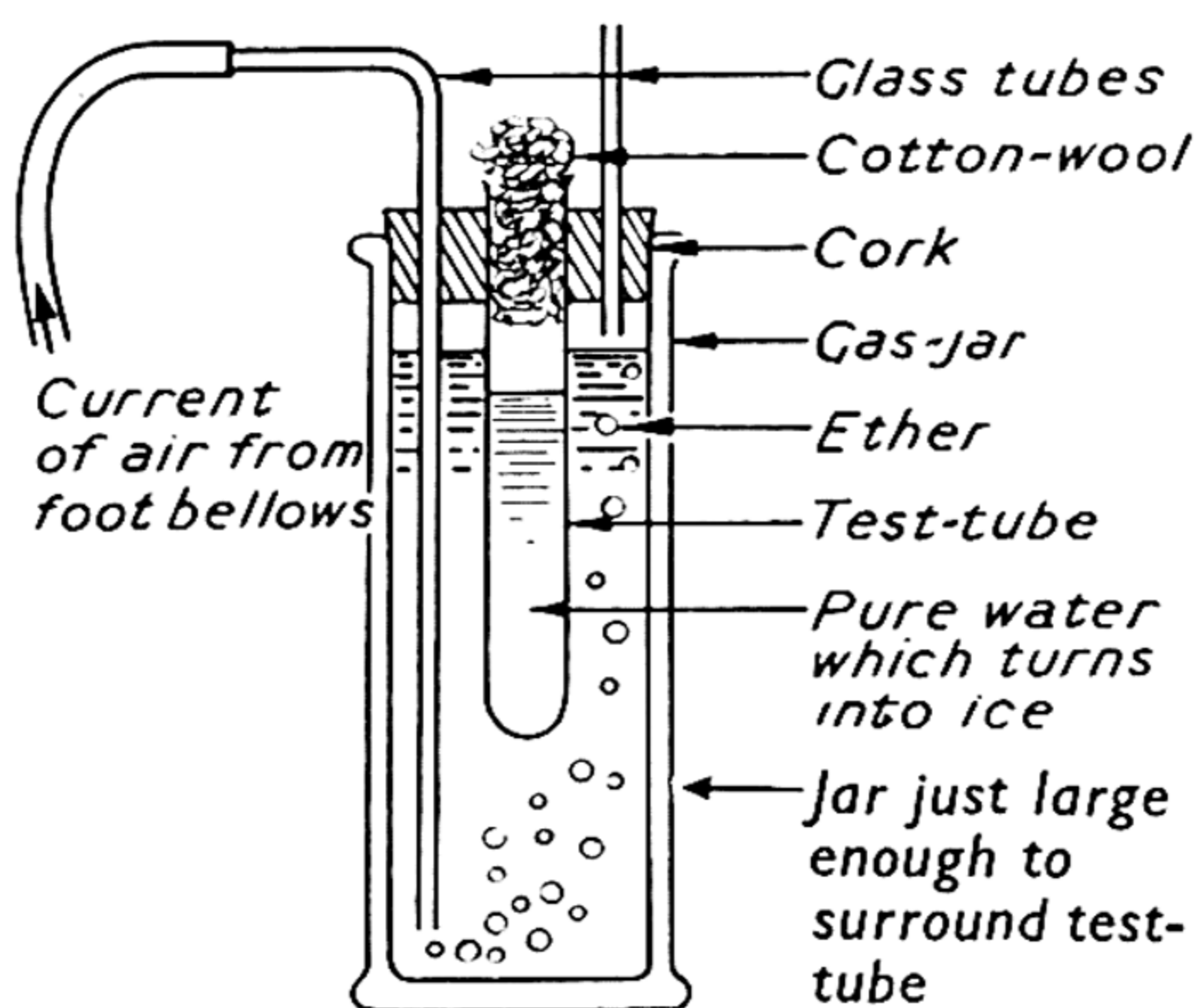
The water in the cocoa-tin should be boiled. When steam is

issuing freely the magnesium should be lighted and the wood and Plasticine pressed firmly down into the position illustrated. The burning magnesium combines with the oxygen from the steam, and hydrogen passes over into the gas-jar.

Various ways of producing water by burning hydrogen are described in some of the books recommended below. The experiment should always be performed by the teacher, and the utmost care should be taken. The whole apparatus should be covered with a towel.

The formation of water on a cold surface when coal-gas burns should be demonstrated and the presence of hydrogen in coal-gas thus shown.

Producing Ice in the Science Room



Important

There must be good ventilation in the room and no flames near.

Use as little ether as possible.

FIG. 76. MAKING ICE

Further Information

Other experiments and further information on this topic are contained in the following books, details of which are given in Chapter VII:

ANDRADE, E. N. DA C., AND HUXLEY, J.: *Things around Us* ("Science for Seniors," Book I).

ANDRADE, E. N. DA C., AND HUXLEY, J.: *Forces at Work* ("Science for Seniors," Book III).

BRAY, F.: *Elementary Science*.

EDSER, E.: *Heat for Advanced Students*.

FREWIN, J. G.: *A New Experimental Science*, Part I.

HART-SMITH, J., AND E. M.: *A First Book of Home Science*.

See also pp. 13–19 of *Everyday Science Topics*, Book II.

Film

Refrigeration (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Electro-Chemistry (16 mm., sound, 2 reels) (Elec. Devel. Assoc.).

The Electric Refrigerator (16 mm., sound, 1 reel) (Elec. Devel. Assoc.).

Film-strips

Science in Everyday Life—Ice (Army Kinema Corporation).

Water (Newton and Co., Ltd).

(J) Coal-gas in the Home

In connexion with this topic it is absolutely essential to have all the appliances mentioned for use in the science room. It is usually possible to borrow all the smaller gas appliances from the local gas showrooms, and visits should be made to the showrooms to see the

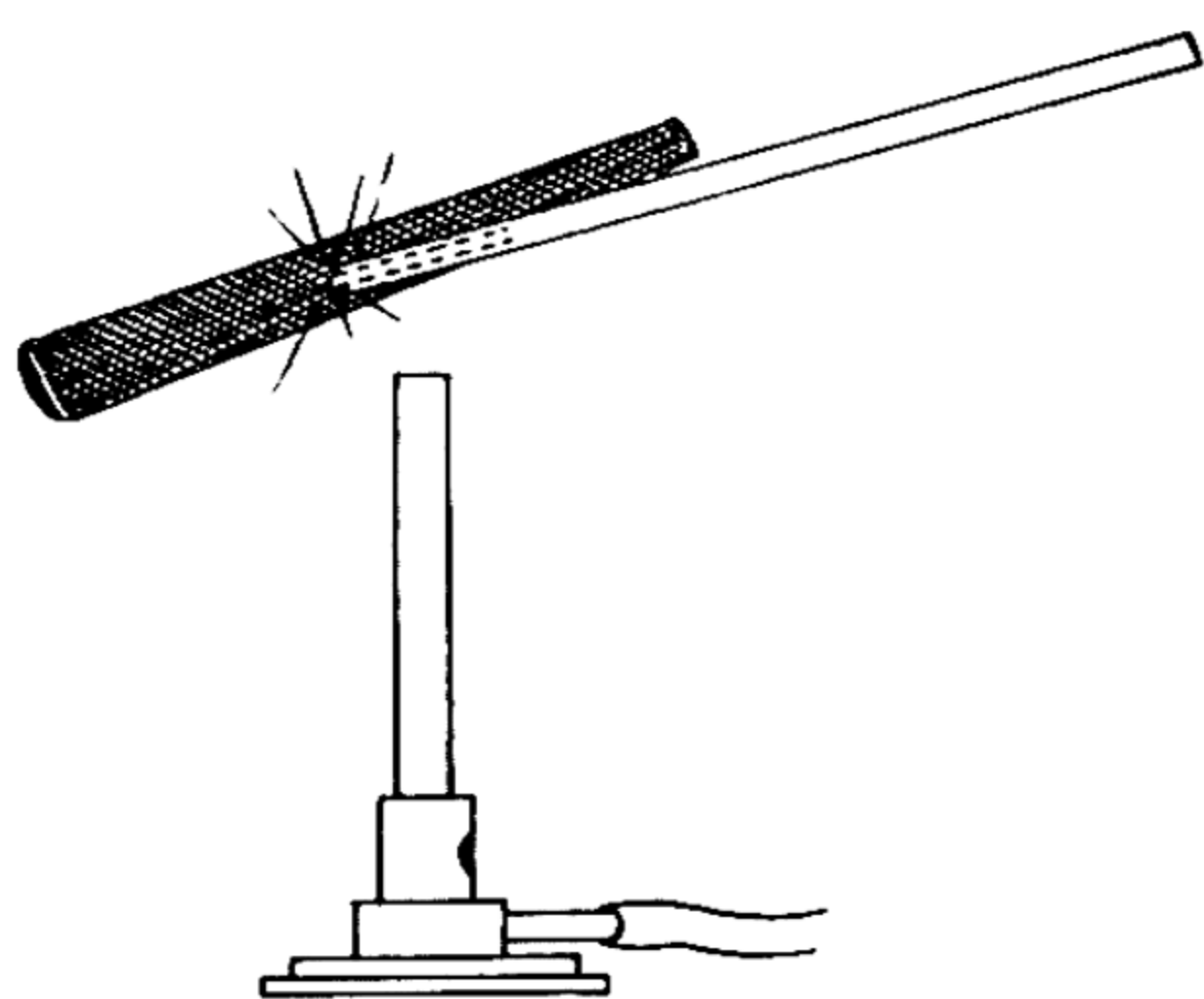


FIG. 77. A GAS-LIGHTER

larger appliances and study their uses. The manager of the showrooms will usually supply booklets describing and illustrating the various appliances.

Pamphlets containing much useful information are obtainable from the British Gas Council, 1 Grosvenor Place, London, S.W.1.

Samples of the various types of gas-taps can usually be obtained from the gas-showrooms manager. These taps

should be compared with water-taps. The pressure of the gas-supply should be compared with the pressure of the water-supply, as was described earlier.

By connecting a gas-tap to a fairly large head of water it can be shown that the plug type of tap is useless for high pressures.

The infinite regulation of heat with a gas-tap should be noted, this not being possible with solid fuel or electricity.

Various ways of lighting the gas should be demonstrated. First, using matches and striking the match before turning on the gas. The effect of turning on the gas and applying a lighted match later should be demonstrated with a gas-fire. The force of the resultant explosion may fracture the radiants.

Gas-lighters

An excellent gas-lighter can be made by drilling a hole in the end of a length of quarter-inch-diameter dowelling, as illustrated above.

Into this hole a piece of flint should be fixed tightly. Sparks are produced by rubbing the lighter along a piece of an old, fairly smooth file. An enormous saving of matches can be effected by the use of these improvised lighters in the laboratory.

Pupils should also be allowed to examine types of electric gas-lighters.

Gas Thermostats

Many manufacturers will supply miniature working models of gas appliances. There should most certainly be in the science room

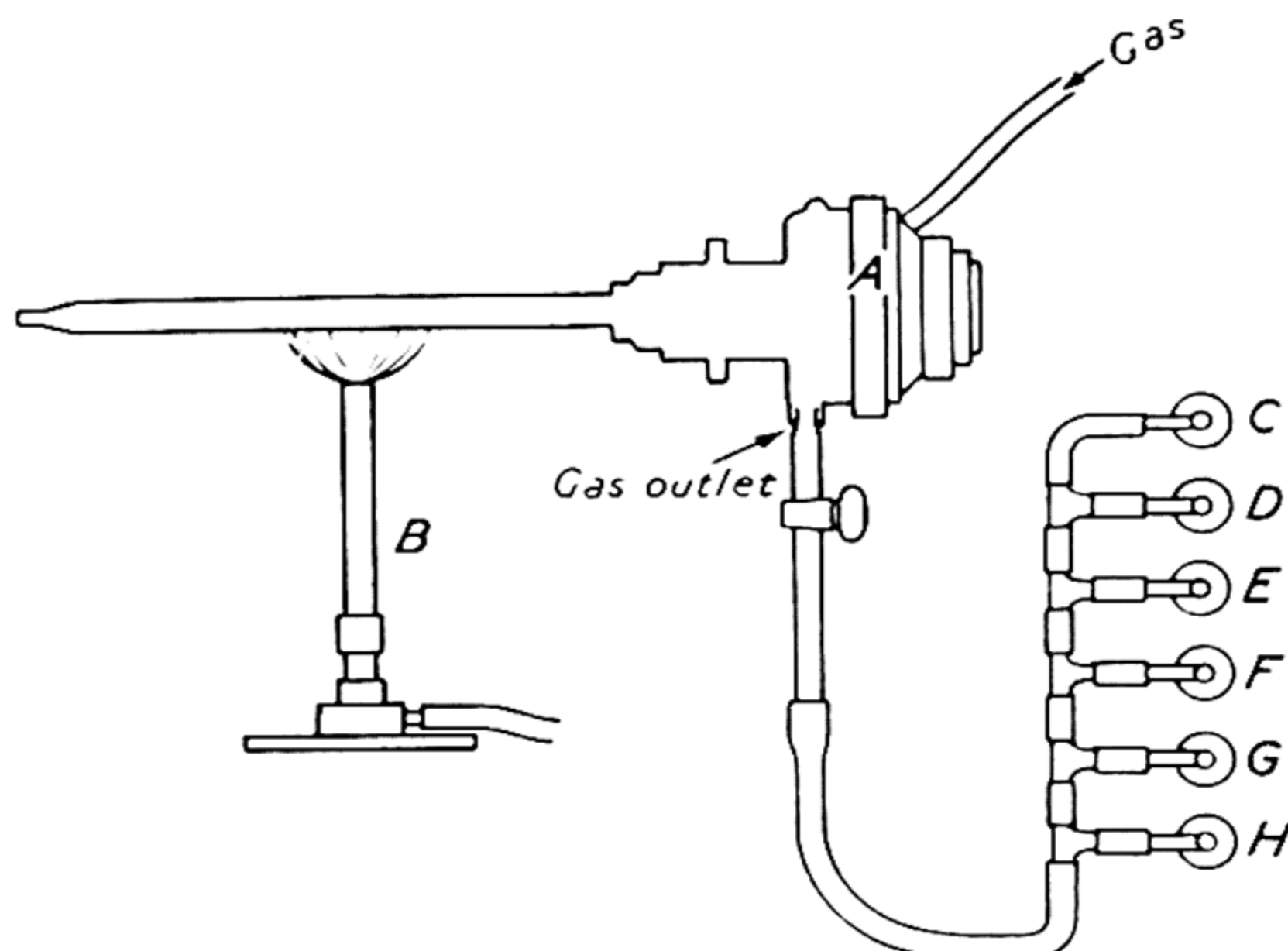


FIG. 78. THE ACTION OF A THERMOSTAT

a working-model thermostat as used in the modern gas-oven and a thermostat in section so that pupils can examine the action of the invar rod, the valve, and the knob and dial. Manufacturers will usually supply these, together with large charts showing how they are constructed.

The action of a working-model thermostat can be demonstrated in the way shown in Fig. 78.

B is a batwing burner placed under the rod of the thermostat. The gas outlet from the thermostat, *A*, is connected by means of rubber tubing and glass T-tubes to a number of Bunsen burners, the total gas consumption of which should be about fifteen cubic feet per hour.

The Bunsen burners, *C*, *D*, *E*, *F*, *G*, and *H*, are lighted, and the effect of turning the knob of the thermostat should be noted. The knob is then turned until the thermostat valve is fully opened and the batwing burner, *B*, is lighted. This demonstrates the action of

cutting down the gas when heat is applied to the rod of the thermostat.

Further Information

Further information on this topic, together with details of further experiments, will be found in the following books, details of which are given in Chapter VII:

- ANNISS, F.: *The New Practical Physics*, Books II, III, and IV.
 BEAN, H. E.: *Everyday Science*, Book I.
 GUTHRIE, J. B.: *Elementary Science*, Part I.
 HADLEY, H. E.: *Everyday Physics*.
 HEDDEN, E. M.: *Science in Housecraft*.
 LITTLE, W. B.: *General Elementary Science*.
 LITTLE, W. B.: *Science in the Home*.
 LOW, A. M.: *Popular Scientific Recreations*.
 LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book I.
 MACDOUGALL, A. T.: *Nature's Mystic Movements*.
 MACDOUGALL, A. T.: *The Marvels of Chemistry*.
 MANFIELD, G. W.: *Modern Science*.
 MARSHALL, F. J. C.: *Science of our Daily Life*, Book II.
 RAY, C. (Editor): *The Boy's Book of Popular Science*.
 SCARR, W. A.: *Science in Common Things*, Book I.
 SPEAKMAN, C.: *Handwork Science*, Book I.
 WHIPPLE, A. H.: *Hygiene of the Home*.

See also pp. 20–29 of *Everyday Science Topics*, Book II.

Films

Several excellent 16 mm. silent and sound films are available on free loan from the British Gas Council, 1 Grosvenor Place, London, S.W.1.

Other Visual Aids

Set of twelve Charts on Gas (Educational Productions, Ltd).

(K) Electricity in the Home

(I) DOMESTIC APPLIANCES WORKED BY ELECTRIC MOTORS

The smaller electric appliances may be borrowed from the local electricity showrooms for use in the science room, and a visit should be made to the showrooms to see the larger appliances working. Ample supplies of illustrations and pamphlets describing the appliances can be obtained from the manufacturers. The posters issued by the Electrical Association for Women, illustrating the uses of electrical labour-saving devices in the home, should be on exhibition in the science room while this topic is under discussion. Copies of these posters can usually be obtained from the local electricity showrooms or direct from the Association.

Further Information

The following books, details of which are given in Chapter VII, will be found helpful in connexion with this topic:

- ANNISS, F.: *The New Practical Physics*, Book II.
CUTTING, T. A.: *Electric Fun*.
DE RATTI, A.: *Small Electric Motors*.
GROVE, R. B.: *Practical Science for Senior Pupils*.
HADLEY, H. E.: *Everyday Physics*.
JOHNSON, V. E.: *Electrical Recreations*.
LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book III.
MACDOUGALL, A. T.: *The Wonders of Electricity*.
MANFIELD, G. W.: *Practical Science for Seniors*, Book III.
MARSHALL, F. J. C.: *Science of our Daily Life*, Books III and IV.
MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.
ROLLER, E., AND PRICKS, H.: *School Experiments in Electricity*.
SCARR, W. A.: *Science in Common Things*, Book III.
WHITE, W. B., AND WATSON, T.: *Handicraft in the Senior School*.

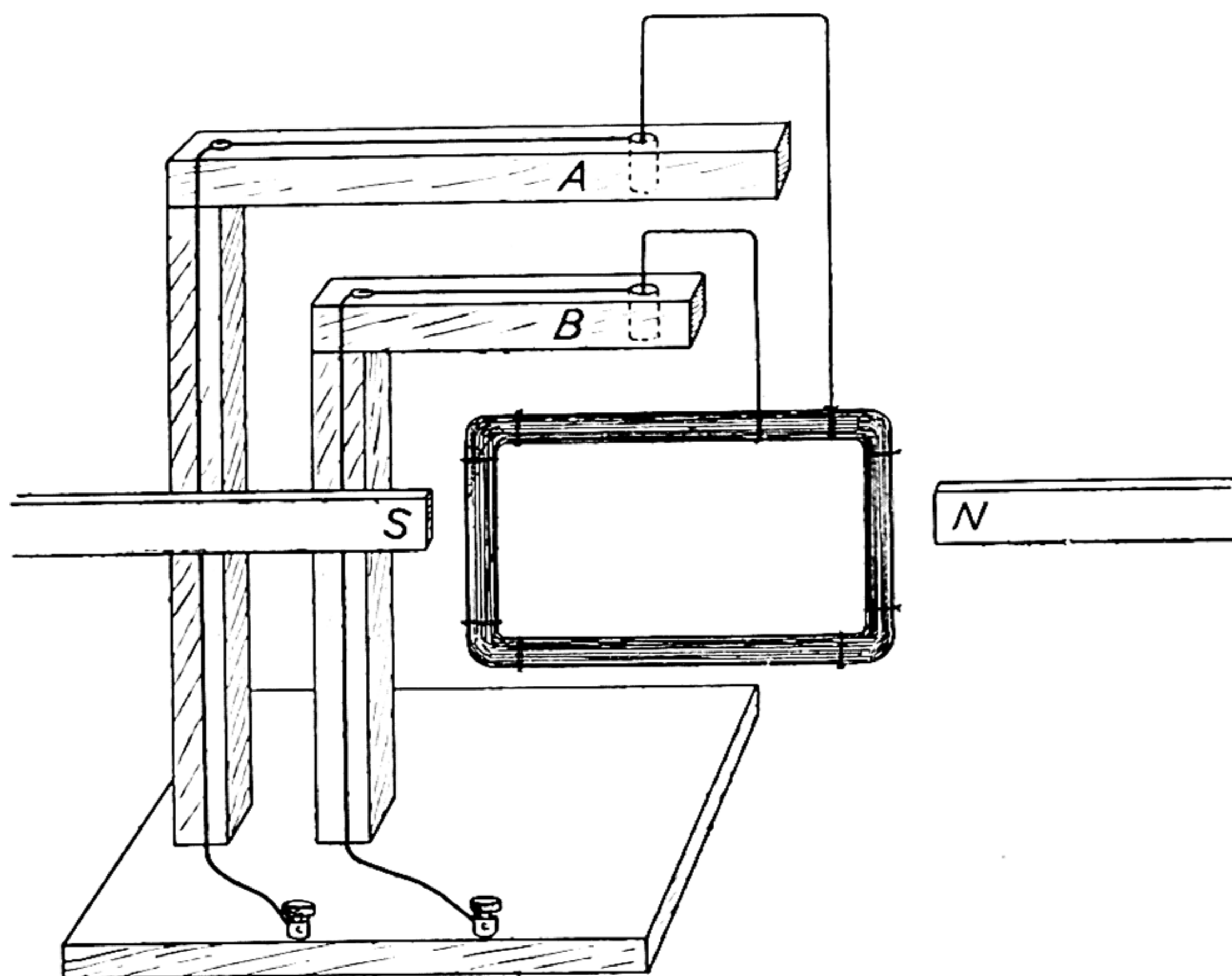


FIG. 79 (a). DEMONSTRATING THE PRINCIPLE OF THE ELECTRIC MOTOR

[See p. 106.]

The Principle of the Electric Motor

Two further models to demonstrate the principle applied in the electric motor are illustrated in Fig. 79 (a) and (b).

In the first the rectangular coil should be made from No. 20 D.C.C. wire and should consist of about a dozen turns. The ends of the coil are bared and bent over so as to fit into the $\frac{1}{8}$ -in. diameter holes made in the wooden supports *A* and *B*. Wires lead from these holes to the terminals, and the holes are filled with mercury. In this way an electric current can be sent through the rectangular coil, which is free to turn when bar magnets are held near the coil as in the illustration. The coil sets itself at right angles to the lines of force due to the two magnets. By reversing the direction of the current through the coil, using the current-reverser described in *Everyday Science Topics*, Book I, it can be shown that the direction of motion of the coil is reversed.

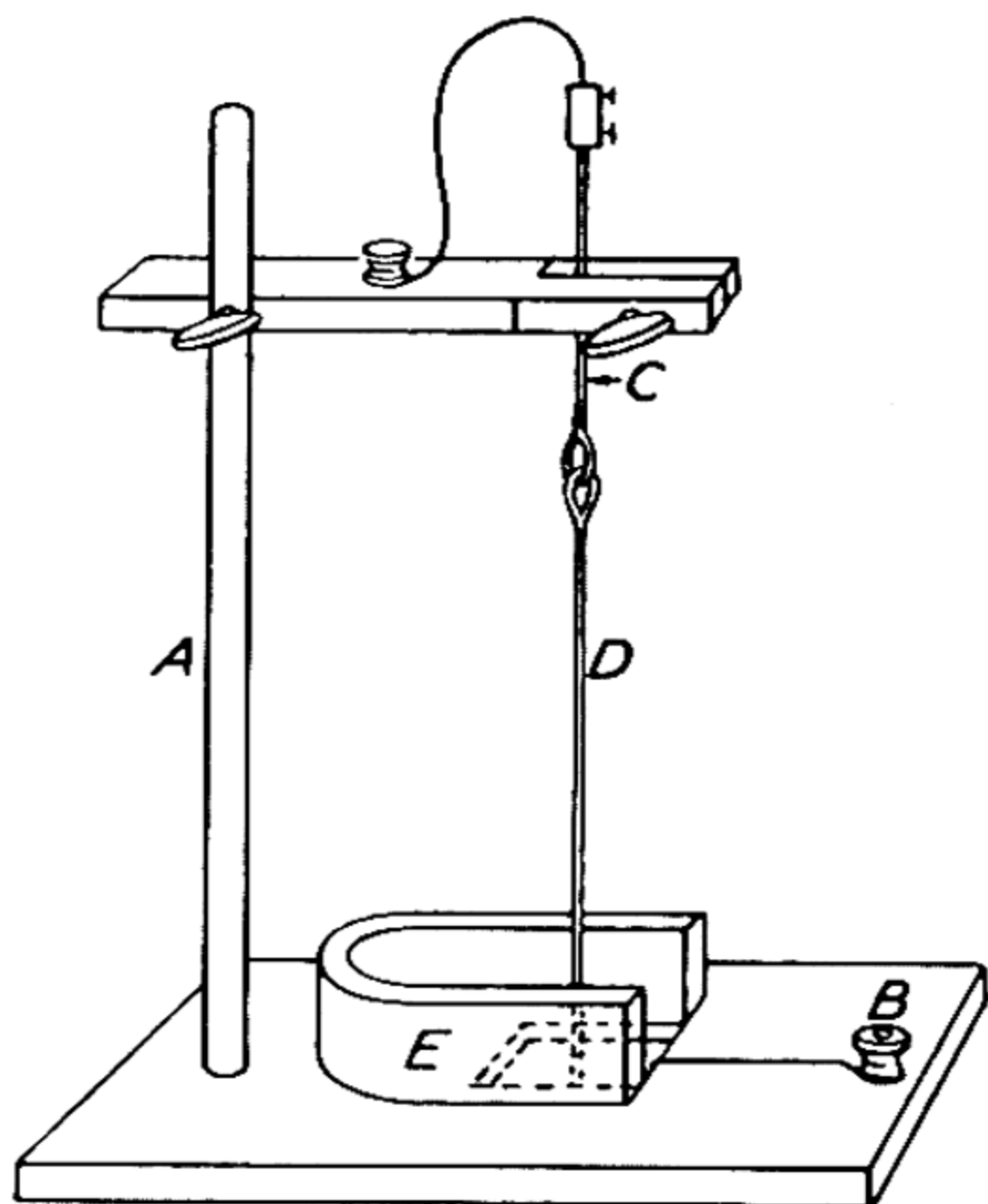


FIG. 79 (b). DEMONSTRATING THE PRINCIPLE OF THE ELECTRIC MOTOR

In the second model *A* is a wooden burette stand. A rectangular hole about 2 in. long, 1 in. wide, and $\frac{3}{8}$ in. deep is cut in the base of the stand. This hole is filled with mercury to a depth of $\frac{1}{4}$ in., and a length of copper wire leads from the terminal *B* and dips into the mercury.

C and *D* are lengths of No. 16 copper wire looped together so that the piece *D* dips into the mercury and is free to move. *E* is a magneto magnet.

The effect of changing the direction of the current through the conductor *D* and of reversing the direction of the lines of force due to the magnet *E* may be demonstrated.

The Magnetic Effects of an Electric Current

Fig. 80 shows a model to demonstrate the magnetic effect of an electric current in a linear conductor.

A is a piece of brass strip about $\frac{1}{4}$ in. wide.

B and *C* are gramophone needles, and *D* is a piece of No. 16 copper wire bent so as to allow the magnetic compass needle *E* to set itself at right angles to the brass strip. The needle *B* is soldered

paper so that the magnetic field can be examined by means of iron filings. The nature of the field and the direction of the lines of force may also be examined by means of small compass needles placed on the horizontal board.

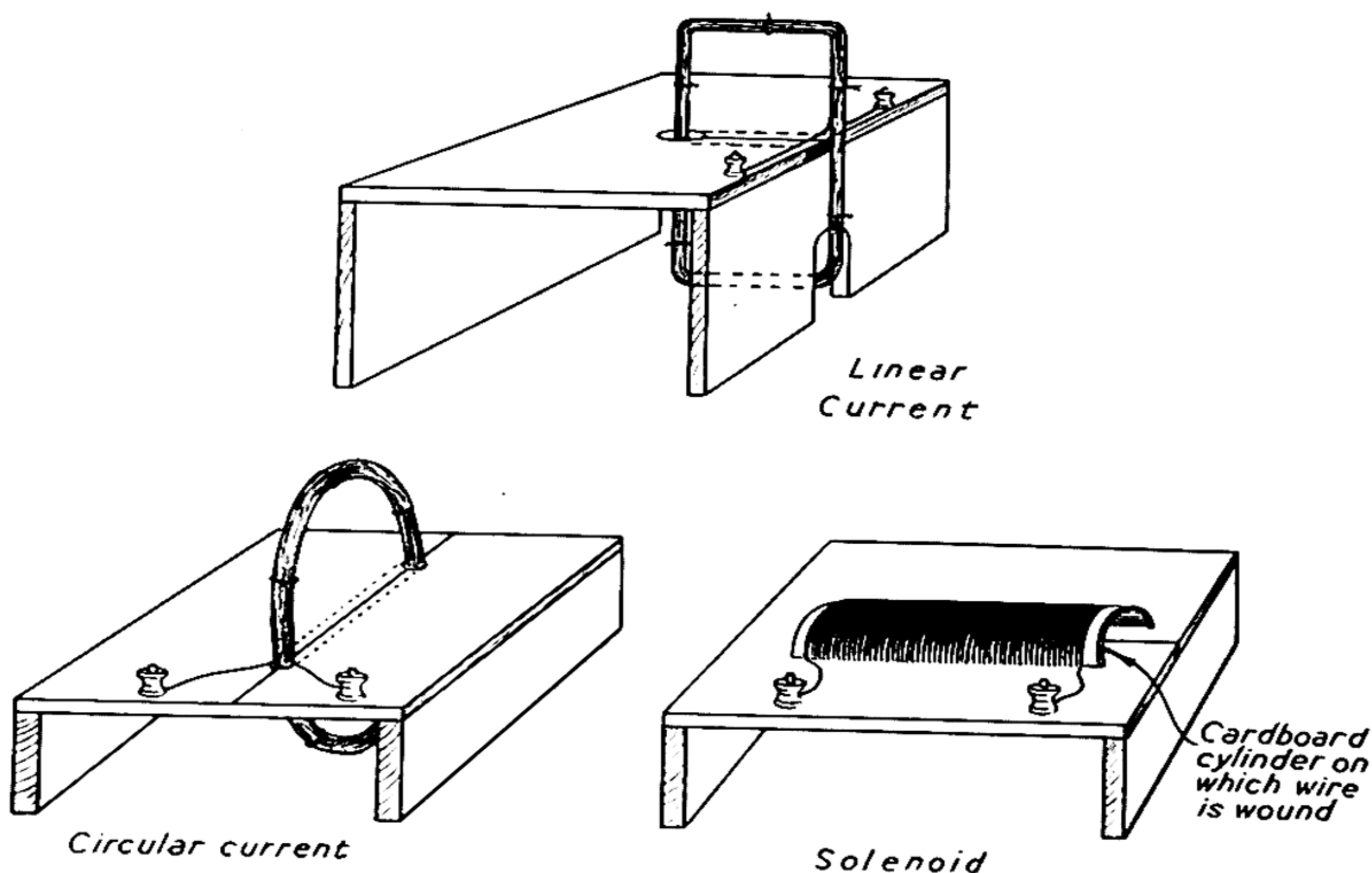


FIG. 82. BOARDS FOR EXAMINING MAGNETIC FIELDS PRODUCED BY ELECTRIC CURRENTS

The solenoid consists of a layer of No. 22 D.C.C. wire on a cardboard cylinder which is fixed in a slot made in the horizontal board.

(II) ELECTRIC LIGHTING

No science teacher should be without *The Teaching of 'Colour' in Elementary Courses of Science*, by Sir E. G. Savage. This excellent little book gives details of many experiments and models which may be used in connexion with this topic. It describes, for example, apparatus which may be used to demonstrate how the colours on the walls of a room may be changed by altering the colour of the incident light (p. 13, Section iv, Fig. 7). An experiment likely to arouse the most apathetic members of a class and illustrating again the dependence of colour upon the nature of the incident light is described at pp. 19 and 20.

Manufacturers may be prepared to help teachers of science in connexion with this topic. This co-operation between manufacturers

and teachers is very valuable, for it is the only way in which teaching may be kept really up to date. It is advisable always to enclose a large stamped and addressed envelope with requests for assistance.

Two excellent little books, *Lamp Quality* and *The Manufacture of Electric Lamps*, have been published by the British Thomson-Houston Company, Ltd. Both books are illustrated.

It may be possible to obtain from manufacturers a showcase of samples showing the stages in the manufacture of electric lamps and a mercury-vapour lamp with auxiliary equipment. From similar sources it is usually possible to obtain the following:

- (1) Particulars of illumination meters and probably the loan of an actual meter.
- (2) Samples of filaments, models of coiled and coiled-coil filaments, and other teaching models.
- (3) Illustrated catalogues, pamphlets, etc. Many of these are beautifully illustrated and are excellent for use with the episcopes.

The Electric Lamp Manufacturers' Association Lighting Service Bureau, 2 Savoy Hill, London, W.C.2, may be prepared to help teachers. They issue an excellent series of illustrated handbooks on electric illumination. Handbook No. 4B, on "Home Lighting," is a particularly helpful book. Handbook No. 2D, on "Illumination Design and Data," also contains much helpful information and a chart of samples showing the proportions of light reflected by walls and ceilings of various colours. The E.L.M.A. also issue a booklet, "A History of the British Electric Lamp Industry."

The Low Pressure in Electric Lamps

A method of demonstrating the low pressure is to take a worn-out lamp. Remove the brass cap and, placing it under water, break off at the point where the bulb has been sealed with a pair of pliers. Pupils should note that no air-bubbles rise to the surface of the water as the water rushes into the bulb, and also that a tiny bubble of gas can be seen inside the bulb, this being the original amount of gas which was present in the lamp. The bang caused by allowing a worn-out electric lamp to crash to the floor is due, like thunder, to air rushing to fill a space where there was a vacuum.

With a length of tungsten or nichrome wire the heating effect of an electric current can be demonstrated. It can also be shown that it is impossible to make the wire hot enough to give light when it is surrounded by air.

The effect of using lamps of the wrong voltage can be demonstrated

with a 3.5-volt lamp. If such a lamp is run on 2.5 volts the light is dim. If it is run on 4.5 volts the light is very bright, but the lamp is very quickly worn out.

A Model Illumination Meter

There should be an illumination meter in the science room when this topic is under discussion so that the intensity of illumination at different places and in varying directions can be compared. Such a

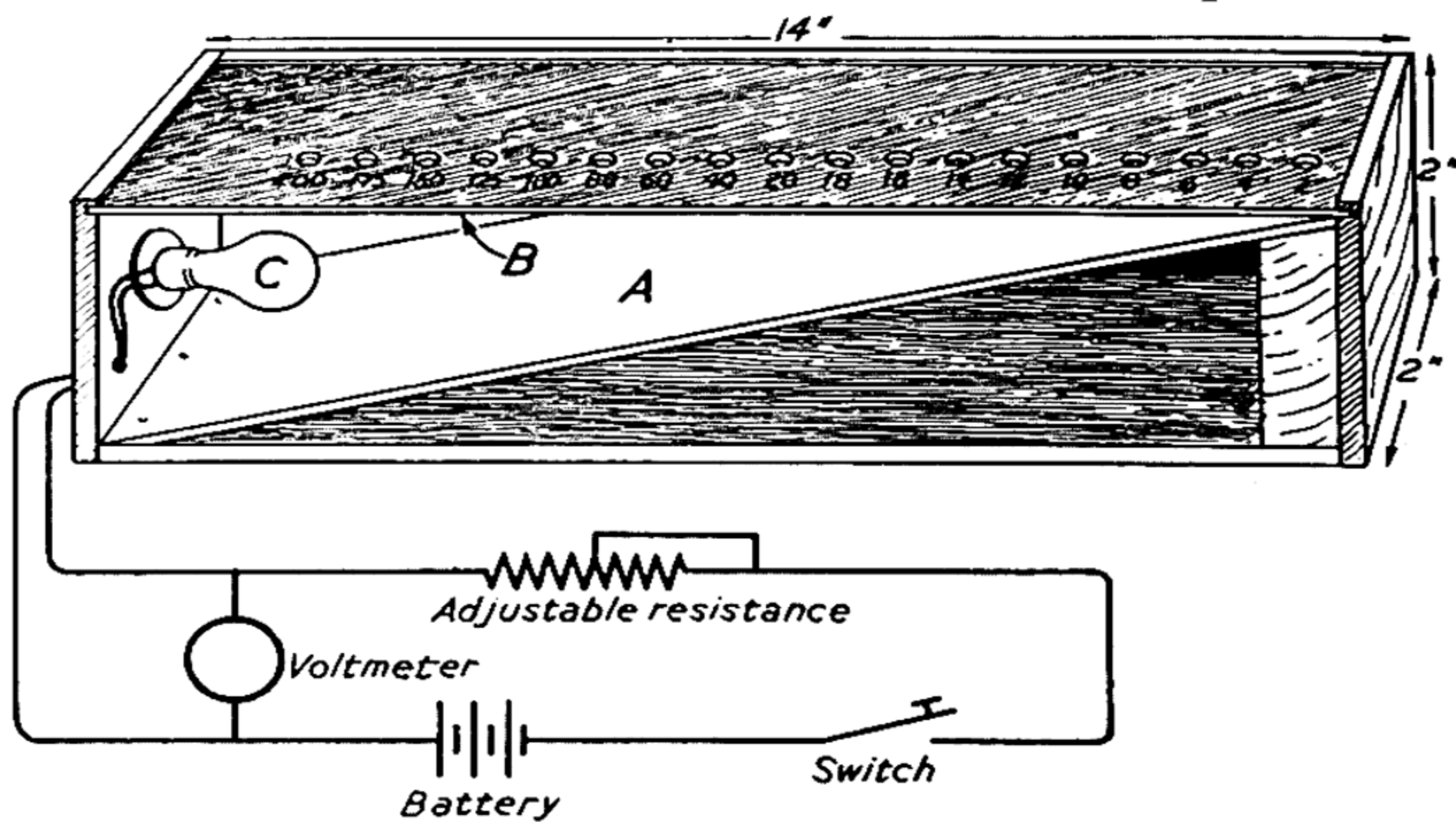


FIG. 83. MODEL ILLUMINATION METER

meter, together with instructions and tables of recommended illuminations, can sometimes be borrowed from manufacturers or from the local electricity showrooms.

A model illumination meter may be made, and then calibrated by comparing with a reliable meter. A simple model illumination meter is shown in Fig. 83, with one side of the meter removed to show the inside. It consists of a wooden box with a piece of three-ply wood, *A*, fixed inside. At one end of the box is fixed a 3.5-volt lamp, *C*. The whole of the upper division of the box inside is painted flat white.

B is a piece of ground glass, and over this is fixed a piece of dead-white paper or cardboard. Holes about $\frac{3}{16}$ in. in diameter and 1 cm. apart are made in this white paper or cardboard.

The lamp *C* should always be joined in circuit with an adjustable resistance and a voltmeter when the model is in use, so that the fall of potential across the lamp can always be made constant. In this way *C* will have a constant illuminating power.

To calibrate the model illumination meter for future use the lamp

C should be lighted and the meter must be placed alongside an actual meter. A 230-volt pearl electric lamp should be placed at various distances in front of the two meters. The experiment should be carried out in a darkened room. The reading of the intensity of illumination registered by the actual meter is noted for each position of the lamp. The holes in the white paper of the model meter are then examined, and a hole is found which appears exactly like the surrounding white paper. At this hole the amount of light passing into the meter is equivalent to the amount of light passing out. Under this hole the illumination in foot-candles (the unit of intensity of illumination), as given by the actual meter, is noted.

By means of this model illumination meter the light intensity at various places and in varying directions may be measured and compared with the recommended illumination, as given in the tables. It will generally be found that the actual illumination indoors is considerably less than that recommended to avoid eye-strain.

If an illumination meter of the Weston type (in which a photo-electric cell is used) can be obtained, it is most interesting to examine with it the low reflection factors of dark-coloured walls by turning the instrument, first towards the wall, then towards a sheet of white paper placed on the wall.

The light absorbed by cigarette smoke and dirty electric-lamp fittings can also be demonstrated.

To show how the Colour of the Walls of a Room may be changed by varying the Colour of the Incident Light

Four pieces of white cardboard coloured with flat washes to match the standard distemper colours represent the walls and ceiling of the room. These pieces of cardboard are pinned inside the box. There should be several sets of colours available so that the colours of the walls and ceiling may be changed.

A, *B*, *C*, *D*, and *E* are 230-volt electric lamps wired to the switches at the side of the box (see wiring diagram), so that any lamp or combination of lamps may be switched on. *A* is an ordinary pearl lamp, which enables pupils to examine the colour of the walls under the usual conditions of electric illumination. *B* is a daylight-blue lamp, which enables the pupils to examine the colour of the walls under daylight conditions. *C*, *D*, and *E* are colour-sprayed lamps. *C* is red, *D* yellow, and *E* blue. By combining these a variety of different colour effects can be obtained. For example, besides the three primary colours of the lamps to be obtained by putting each in circuit separately, a purple illumination can be obtained by switching on the red and blue bulbs together, green by using the

yellow and blue together, orange by combining the yellow and red, and so on.

Tin-plate reflectors must be fitted round each lamp to reflect the light into the box, and the general effect is better observed when a

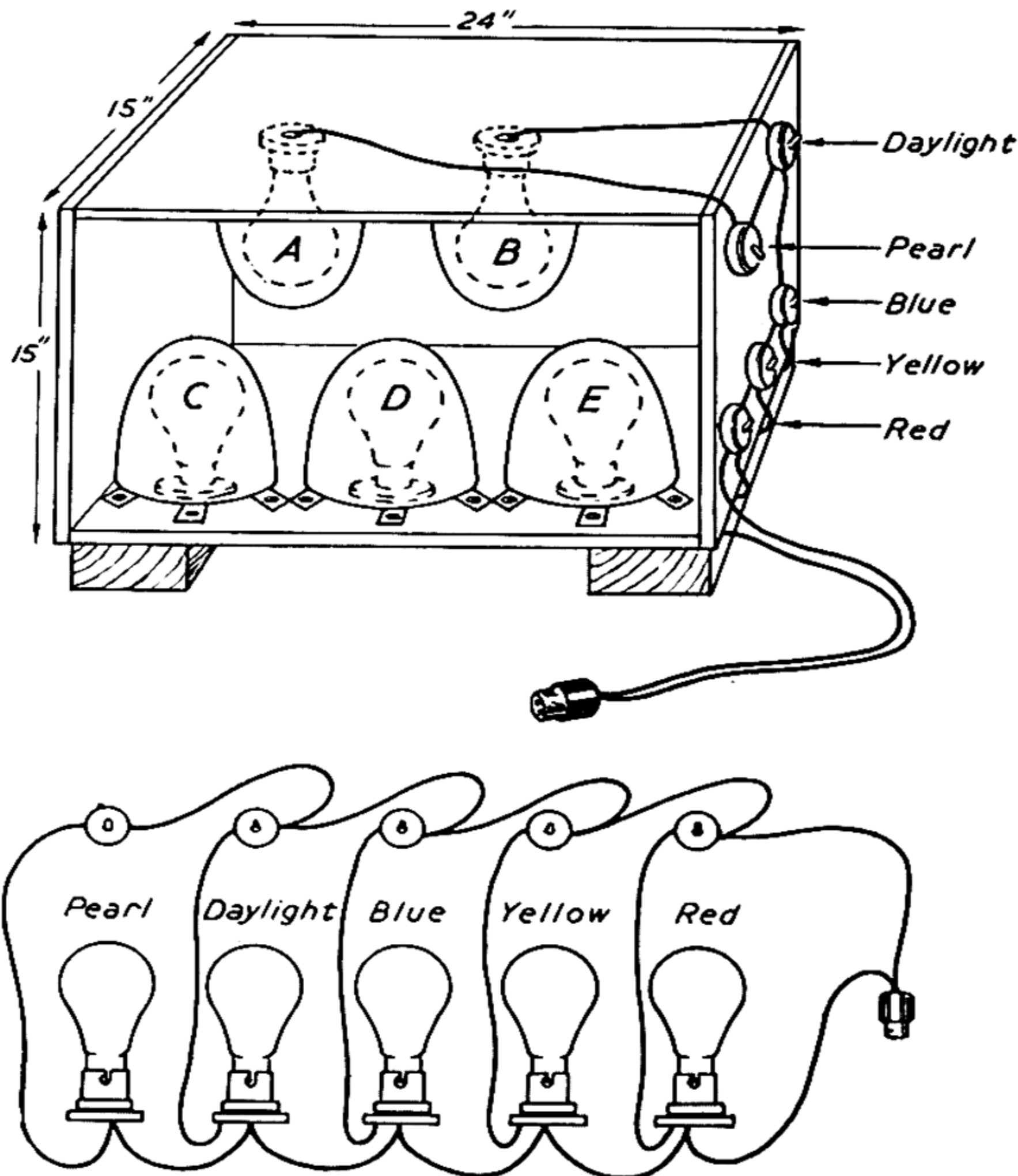


FIG. 84. VARYING THE COLOUR OF WALLS BY THE USE OF LIGHTS

sliding ground-glass screen is fitted in the front of the box.

A smaller model can be made using small decoration lamps.

To show how the Colour of the Incident Light alters the Appearance of Coloured Materials

The model shown in Fig. 85 consists of a wooden box with a sliding front of three-ply. A square piece is cut out of the lower part of the three-ply front, and a piece of clear glass can be fitted. *A* is a sloping piece of three-ply held in position with nails. It is intended to hold the pieces of coloured materials which are to be examined.

B is a 230-volt pearl lamp and *C* is a daylight-blue lamp. These

lamps are wired to the switches *D* and *E*, so that each may be lighted separately. The method of wiring is similar to that illustrated in the last section, but for two lamps and switches only.

Old pattern books can usually be obtained from tailors, and these supply all the samples of coloured materials necessary.

A piece of coloured material is laid on *A* and held in position with two drawing-pins. The sliding front is pushed into position, and the

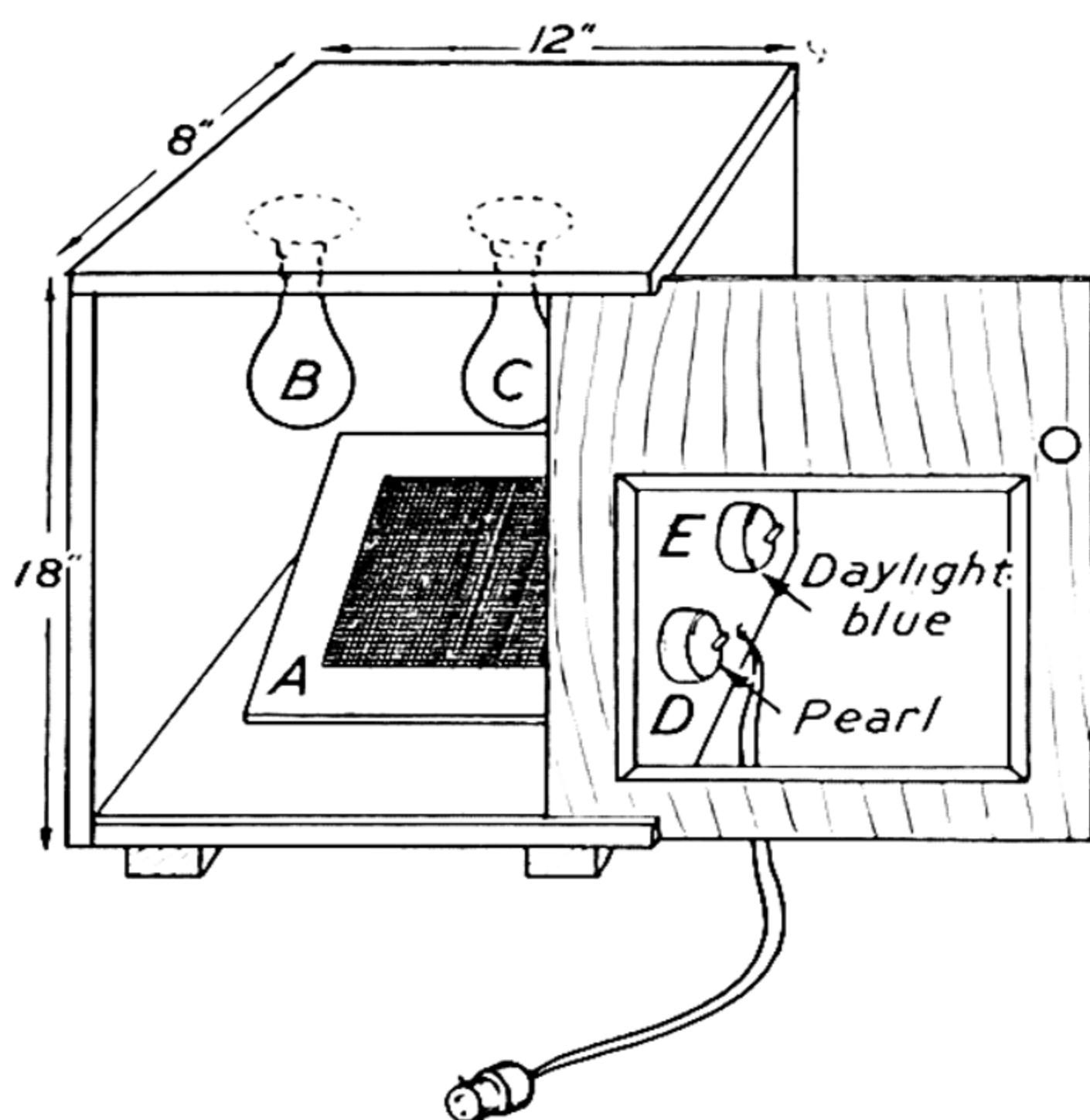


FIG. 85. TO SHOW THE EFFECT OF ARTIFICIAL LIGHT ON COLOURED MATERIAL

appearance of the material is examined, first with lamp *B* lighted, then with lamp *C*.

With most samples of coloured materials the colours are quite different when viewed under the two different kinds of light.

Again, it is interesting to match two colours under the light from lamp *B*, then, on switching off lamp *B* and switching on lamp *C*, it will very often be found that the colours are no longer matched.

Further Information

Further information on this topic will be found in the following books, details of which are given in Chapter VII:

ANNISS, F.: *The New Practical Physics*, Book III.

HADLEY, H. E.: *Everyday Physics*.

LITTLE, W. B.: *Science in the Home*.

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Books II and III.

MACDOUGALL, A. T.: *The Wonders of Electricity*.

MARSHALL, F. J. C.: *Science of our Daily Life*, Book III.

ROYDS, A.: *How it acts*.

WHIPPLE, A. H.: *Hygiene of the Home*.

(III) WIRING HOUSES FOR ELECTRICAL EQUIPMENT

How Electricity is distributed in a House

The model illustrated in Exercise 38 of *Everyday Science Topics*, Book II, shows a method of teaching pupils how the electric current is distributed in a house. The appliances and cables used are the same as those usually fitted in the home. The meter, main fuses, main switch, and distribution box can be obtained from manufacturers, or from the local Electricity Department. The apparatus is fitted to a vertical wooden stand about 7 ft. long and 3 ft. high.

The main lead-in cable, *E*, may be fitted to a 15-amp. power-point in the laboratory, and 15-amp. fuse-wire is fitted in the main fuses. The meter illustrated is of the prepayment type. By removing the thumb-screw at *F* the cover of the meter may be removed and the action of the meter mechanism may be observed.

It should be made clear to the pupils that the meter and main fuses are always sealed in actual practice, because the current supply to these cannot be cut off, and to prevent interference with the meter.

The method of wiring up the main fuses, meter, main switch, and distribution-box is usually indicated on the appliances, or in the literature supplied with the appliances, if they are obtained from the manufacturers.

The right-hand part of the stand is divided up into sections to represent rooms by screwing to it wooden boards $\frac{3}{4}$ in. thick and 6 in. wide. The ceiling roses are fixed to these boards.

The cables leading from the distribution-box to the rooms are taken behind the stand. Large diagrams of the circuits should be placed near the model for reference. The fuse-holders in the distribution-box should be numbered.

With this model pupils may learn how to wire up a house for electric light and power, how to connect lamps in parallel, as in room C, how to wire up a two-way circuit, as on the stairway, and how to use actual switches, lamp-holders, ceiling roses, switch-sockets, plugs, and adaptors. They see how the main switch cuts off the supply to the distribution-box and, hence, to the whole house. When fuse-wires are to be replaced, or switches and lamp

holders are to be repaired, the main switch must be turned off so that there is no danger of receiving an electric shock.

To demonstrate the action of the fuses a lighting circuit can be overloaded by connecting a two-kilowatt electric fire to the lamp-holder in room *D*, or by causing a short circuit. The fuse-wire melts, thus preventing the excessive current from overheating the cables and setting fire to the house.

The action of the meter may also be studied. The speed of the rotating disc can be observed with various loads by switching on various numbers of lights; the wattage consumption of any given lamp or other electrical appliance can be measured or checked, and the cost of using the appliances can be calculated.

Where a prepayment mechanism is attached to the meter this can be tested. For example, in a district where electricity is threepence a unit, when a penny is inserted in the meter it should allow enough electricity to pass to light a two-kilowatt electric fire for ten minutes. The current-supply should then fail until another penny is inserted.

The pupils should, of course, learn how to read the meter, and also why so much care must be taken to cover all terminals in switches, etc. They should also be allowed to examine how the cables and flex are wrapped with insulating material.

The insulating properties of the lighting cables can be compared with the insulating power of double-cotton-covered copper wire by connecting lengths to the secondary terminals of an induction coil.

Where there is no current supply in the laboratory the model house can be wired up for electric light, using miniature lamps and batteries.

Further Information

Further information on this topic will be found in the following books, details of which are given in Chapter VII:

- ALLSOP, F. C.: *Practical Electric Light Fitting*.
 ANDRADE, E. N. DA C., AND HUXLEY, J.: *Forces at Work*.
 BOTTONE, S. R.: *A Guide to Electric Lighting for Householders and Amateurs*.
 BROOK, C. B.: *Electricity in the Home*.
 COWLEY, H. H.: *Modern Electrical Wiring*.
Electrical Handbook for Women (Electrical Association for Women).

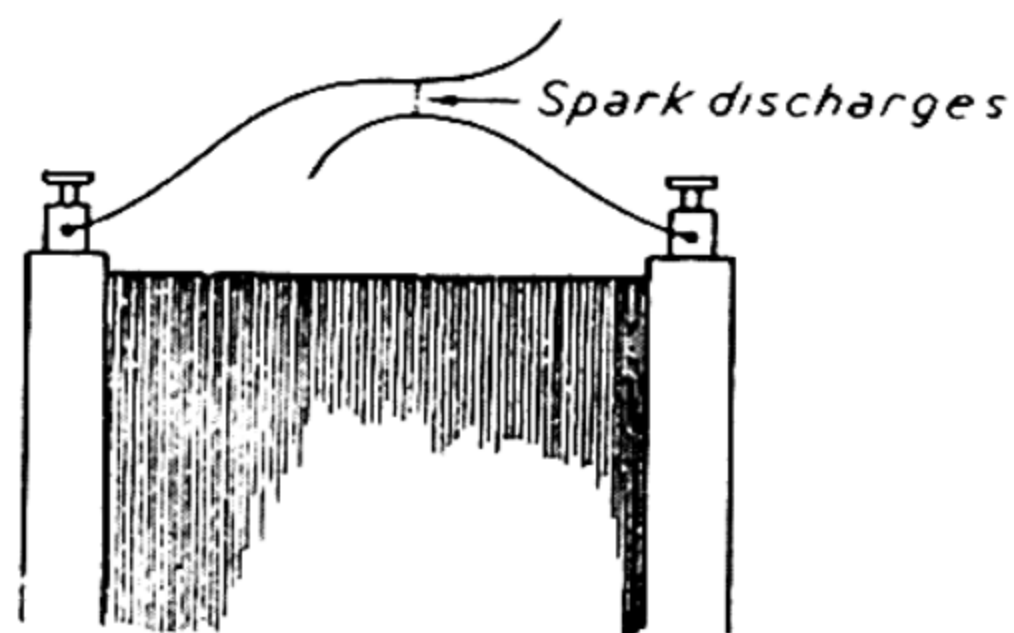


FIG. 86. COMPARING THE INSULATING PROPERTIES OF LIGHTING CABLE AND COPPER WIRE

HADLEY, H. E.: *Everyday Physics*.

MANFIELD, G. W.: *Practical Science for Seniors*, Book III.

MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.

Regulations for the Electrical Equipment of Buildings.

ROGET, S. R.: *A First Book of Applied Electricity*.

SCARR, W. A.: *Science in Common Things*, Book III.

TAYLOR, F. H.: *Private House Electric Lighting*.

See also pp. 30–55 of *Everyday Science Topics*, Book II.

Films

All Electric House (16 mm., silent, 1 reel) (Electrical Association for Women).

Current Electricity (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Illumination (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Induced Currents (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Heat and Light from Electricity (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Simple Electrical Repairs at Home (16 mm., sound or silent, 1 reel) (British Electrical Development Association).

The Behaviour of Light (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

The Electric Circuit of the House (16 mm., sound, 1 reel) (British Elec. Devel. Assoc.). The details apply also to the following six films, except where otherwise indicated.

The Electric Cleaner (British Elec. Devel. Assoc.).

Electricity and Light (2 reels) (British Elec. Devel. Assoc.).

Electricity and Heat (British Elec. Devel. Assoc.).

Electricity and Movement (British Elec. Devel. Assoc.).

The Electric Refrigerator (British Elec. Devel. Assoc.).

The Electric Iron (sound or silent) (British Elec. Devel. Assoc.).

Film-strips

A Simple Electric Circuit (Army Kinema Corporation).

Don't be Shocked—Precautions against Electric Shock (Unicorn Head, Ltd).

Electrical Appliances (Common Ground, Ltd).

Electrical Safety (Army Kinema Corporation).

Electrical Safety (Dance-Kaufmann, Ltd).

Electricity and Magnetism Introduction (Common Ground, Ltd).

Electricity in the Home (Army Kinema Corporation).

Electricity in the Home. Lighting and Power (Educational Productions).

Light into Colour (Unicorn Head, Ltd).

The Vacuum Cleaner (Army Kinema Corporation).

Uses of Electricity (Army Kinema Corporation).

Film Strips and Lantern-slides with Lecture Notes

The British Electrical Development Association (Inc.) issue these slides:

Better Light—Better Sight; Healing the Sick and helping the Injured; Michael Faraday; Plug Points and their Uses; Using Electricity Economically.

Other Visual Aids

Set of twelve Charts on Electricity (Educational Productions, Ltd).

Visual Book, *Electricity in your Home* (Educational Productions, Ltd).

Wall Sheets: *Electricity Made Easy* (Electrical Association for Women).

Booklet: *For those who may not know* (British Elec. Devel. Assoc.).

(L) Coal-gas Supply

The experiments described in Exercises 39 and 40 of *Everyday Science Topics*, Book II, serve as a good introduction to this topic.

A copy of the leaflet *A Visit to the Gasworks*, if still available, should be given to each pupil. This leaflet gives a short account of the various processes in the manufacture of town gas and the recovery of the many by-products. Inquiries should be made to the local gasworks or the British Gas Council, 1 Grosvenor Place, London, S.W.1.

Other useful illustrated pamphlets which may still be available from the Gas Council are: *The Romance of a Lump of Coal*; *What a Therm of Gas will do*; *Practical Hints on Gas Economy*; *A Therm of Gas and —*; *Not a Cold Corner in the House*.

A large diagrammatic representation of the plant actually used at the local gasworks, with the names of the parts and their functions clearly indicated, should be on exhibition in the science room during discussion of this topic. Such a diagram, and often a model used at the gasworks for the instruction of visitors, may be borrowed from the manager so that copies may be made of them. Information as to the uses and destinations of the by-products obtained at the gasworks can also be obtained on application, and should be noted on the diagram of the works. After this preliminary work arrangements should be made for the pupils to visit the local gasworks.

A plan of the town, showing the situation of the works and the main distribution pipes, with the height above sea-level marked in various places, will also be very helpful. This plan should be compared with the plan showing the distribution of water.

The Pressure of the Gas-supply

It is helpful if pupils living in low and high parts of the town can measure the pressure of their gas-supply with a water manometer. A record of pressures and heights above sea-level can then be made.

By connecting a water manometer to a gas-tap, noting the pressure of the gas in centimetres of water, and then opening all other gas-taps in the laboratory, the fall in pressure at the tap connected to the manometer may be noted. The fall in pressure during certain periods of the day may thus be demonstrated.

Further Information

Further information on this topic will be found in the following books, details of which are given in Chapter VII:

ANDRADE, E. N. DA C., AND HUXLEY, J.: *An Introduction to Science*, Book III.

ANDRADE, E. N. DA C., AND HUXLEY, J.: *Forces at Work*.

ANNISS, F.: *The New Practical Physics*, Book II.

Gas Manufacture, Distribution, and Use. Notes for Teachers.

LITTLE, W. B.: *Science in the City*.

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book II.

MACDOUGALL, A. T.: *The Marvels of Chemistry*.

See also pp. 56–63 of *Everyday Science Topics*, Book II.

Films

Buried Treasure (16 mm., sound and silent, 3 reels) (G.B. Film Library).

It comes from Coal (16 mm., sound, 1 reel) (The British Gas Council).

On Silent Service (16 mm., sound, 1 reel) (The British Gas Council).

The Manufacture of Gas (16 mm., sound or silent, 2 reels) (The British Gas Council).

The Nation's Wealth (16 mm., sound-colour, 1 reel) (The British Gas Council).

The Story of Coal (16 mm., silent, 2 reels) (G.B. Film Library).

Film-strips

Coal and its By-products (British Industrial Films, Ltd).

Gas Industry (Historical) (Common Ground, Ltd).

Gas Industry (Modern) (Common Ground, Ltd).

(M) How Electricity is made and distributed

A discussion of the various ways of producing electricity serves as a suitable method of introducing this topic. Pupils should be shown how charges of electricity can be produced on certain substances by rubbing them. They cannot fail to understand the limitations of such electric charges and their unsuitable nature for everyday use. They will have examined the production of electricity by cells and batteries, and will realize that when much electric power is needed many batteries have to be used. They should now be shown the production of electricity by a dynamo generating direct current and by a dynamo generating alternating current. Such dynamos can be obtained from various sources.

Complete second-hand A.C. and D.C. generating sets can be obtained at very reasonable prices from Electradix, 214 Queenstown Road, London, S.W.8. Catalogues and lists issued by the following

firms will give particulars of suitable equipment at prices ranging from a few shillings: Messrs Bassett-Lowke, Ltd, St Andrew's Street, Northampton; the Economic Electric Company, 64 London Road, Twickenham; Messrs Bond's Ltd, 357 Euston Road, London, N.W.1; Messrs Bowman Models, Dereham, Norfolk; Messrs Stuart Turner, Ltd, Henley-on-Thames; Messrs Griffin and Tatlock, Ltd, Kemble Street, Kingsway, London, W.C.2. Old second-hand generating sets may often be obtained locally for a small sum. The catalogues issued by the Economic Electric Company and Messrs Stuart Turner, Ltd, contain particulars of dynamo construction sets, and those issued by the other firms mentioned contain particulars of steam engines, steam turbines, and water turbines for driving small model dynamos.

A Method of driving Model Dynamos

The illustration in Exercise 48 of *Everyday Science Topics*, Book II, shows a suitable method of driving a small model dynamo. This arrangement has many other uses in the laboratory. An old bicycle-frame can often be purchased for a few shillings. This is mounted on a horizontal board, as shown, and a length of Woolworth's expanding curtain wire makes an excellent belt.

To join two ends of this curtain wire to form the belt pull out about one inch at each end. Holding one end firmly between the thumb and forefinger of the left hand, turn the other end in an anticlockwise direction between the thumb and forefinger of the right hand. After giving it several turns allow it to untwist into the coils of the end held in the left hand. The two ends will then be held firmly together.

A large chart showing the position of the town's electricity works, the main distribution cables, and the transformer stations should be used. Such a chart can usually be borrowed from the manager of the local electricity works.

Various methods of showing the electric current produced in a circuit when the magnetic conditions near it are changing are described in the books mentioned later. For the detection of an induced current a fairly sensitive galvanometer is necessary.

Apparatus for the examination of the magnetic fields of bar magnets and solenoids has been previously described. The use of the apparatus shown in Exercises 45 and 47 of *Everyday Science Topics*, Book II, will enable pupils to see how the movement of these magnetic fields near coils of wire creates induced currents. Only while the bar magnet is moving or when the primary circuit is being made and broken are induced currents produced. In the dynamo coils of

wire are moved near strong magnetic fields or the magnetic fields are moved near coils to produce a continuous induced current.

The Transmission of Electric Power

Exercise 50 of *Everyday Science Topics*, Book II, illustrates apparatus which may be made and used to demonstrate the transmission of electric power, and how alternating current may be changed. It is advisable to demonstrate the heating effect of an electric current before proceeding to discuss transmission. It is not a difficult matter using an ammeter to demonstrate roughly how the heat produced in a length of nichrome wire is proportional to the square of the current which passes through the wire. When a current strength is doubled four times as much energy is converted into heat in the wire.

The reason for insulating carefully high-voltage cables can be demonstrated with a transformer or induction coil. By connecting lengths of D.C.C. wire to the secondary high-voltage terminals it can be shown how the insulating properties of air and cotton break down and also how the current runs to earth if given the opportunity. The need for special switches for high-voltage currents can also be demonstrated by showing how such currents will spark across between the contacts of ordinary switches, igniting any inflammable material placed near.

Arrangements should be made for the pupils to visit the nearest power station. They should be taken first to the furnaces where steam is being generated, then on to the turbines driving the alternators and smaller exciter dynamos. They should be allowed to examine high-voltage switch-gear, cables transmitting various loads, transformers, etc.

Diagrams, charts, and literature are obtainable from the Central Electricity Board. These illustrate and describe the interconnexion of power stations all over Great Britain (the Grid).

A Model Transformer

Exercise 49 of *Everyday Science Topics*, Book II, illustrates a model transformer made from parts supplied by the Electrano Company, London, W.C.1. It is made up of a core of laminated stalloy, the yoke is readily removable, and the coils are interchangeable.

This apparatus can be used:

- (1) To show the production of A.C. in the secondary if A.C. is supplied to the primary.
- (2) To show the effect of the number of turns in the secondary coil on the output voltage.

- (3) To compare the effect of the laminated yoke with a solid iron yoke.
- (4) For the demonstration of transmission.

Picture postcards, photographs, and lantern-slides for use in connexion with this topic can be obtained from the Director, Science Museum, South Kensington, London, S.W.7.

Particulars of rectifiers can be obtained from the Westinghouse Brake and Signal Company, Ltd, 82 York Way, King's Cross, London, N.1. Second-hand transformers and rectifiers can be obtained from the "Radiomart," 19 John Bright Street, Birmingham.

There are numerous films available in connexion with this topic. Valuable films are lent by the British Electrical Development Association, 2 Savoy Hill, London, W.C.2. Particulars will be forwarded on request.

Lecture notes with slides or film strips on the following subjects are issued free to science teachers by the British Electrical Development Association:

Faraday; The Story of an Errand Boy who changed the World; Electric Plug Points and their Uses in the Home; The Generation of Electricity; How Electricity is made and conveyed.

Further Information

Further information and details of further models and experiments will be found in the following books, details of which are given in Chapter VII:

- ANNISS, F.: *The New Practical Physics*, Books III and V.
 BEAN, H. E.: *Everyday Science*, Book III.
 CROWTHER, J. A.: *The Life and Discoveries of Michael Faraday*.
 CUTTING, T. A.: *Electric Fun*.
 GIBSON, C. R.: *The Romance of Modern Electricity*.
 HADLEY, H. E.: *Everyday Physics*.
 HEDDEN, E. M.: *Science in Housecraft*, Book II.
Historical Apparatus ("Modern Science Memoirs").
 HUGHES, A. G., AND PANTON, J. H.: *Elementary General Science*, Book III.
 LEE, J. A.: *The Grid*.
 LITTLE, W. B.: *Science in the City*.
 LITTLE, W. B.: *Science in the Home*.
 MORGAN, A. P., AND SIMS, J. W.: *The Boy Electrician*.
 LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book III.
 MANFIELD, G. W.: *Practical Science for Seniors*, Book III.
 RANDELL, W. L.: *The Romance of Electricity*.
 RAY, C. (Editor): *The Boy's Book of Popular Science*.
 ROLLER, E., AND PRICKS, H.: *School Experiments in Electricity*.

SCARR, W. A.: *Science in Common Things*, Book III.

Wonder Book of Electricity.

See also pp. 64–74 of *Everyday Science Topics*, Book II.

For titles on dynamos see Percival Marshall's list of technical books.

ADLAM, G. H. J. (Editor): *The Science Master's Book*, Series I, Part I (Physics), and Series II, Part I (Physics).

ROGET, S. R.: *A First Book of Applied Electricity*.

Films

"A.C." and "D.C." (16 mm., sound, 1 reel) (British Elec. Devel. Assoc.).
Battery and Dynamo, Part II (16 mm., sound, 1 reel) (Army Kinema Corporation).

Electrical Machines: Single Coil 2 Pole Alternator; Single Coil 2 Pole D.C. Generator; Faraday's Disk Generator; Faraday's Transformer Experiment (16 mm., silent) (Dance-Kaufmann Cycle Films).

Electro-magnetic Induction (16 mm., sound, 2 reels) (Central Film Library).

Generation of Electricity (16 mm., sound or silent, 1 reel) (British Elec. Devel. Assoc.).

Induced Currents (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Power Lines (16 mm., sound, 2 reels) (Central Film Library).

Report on Electricity (16 mm., sound, 1 reel) (Central Film Library).

Transmission of Electricity (16 mm., sound or silent, 1 reel) (British Elec. Devel. Assoc.).

What is Electricity? Part I (16 mm., sound, 1 reel) (British Elec. Devel. Assoc.).

Film-strips

Bulk Distribution of Electricity (British Industrial Films).

Current Electricity (Newton and Company, Ltd).

Development of Power Stations (Common Ground, Ltd).

Electricity. Its Production (British Industrial Films).

Introduction to Alternating Current (Common Ground, Ltd).

(N) Feeding

To show that Chlorophyll can absorb Light-rays

Take an alcoholic solution of chlorophyll—*i.e.*, methylated spirit which has been used to decolorize green leaves. Filter the solution and place in a test-tube. Notice the colour of the extract when held up to the light and when held against a black surface. It is green by transmitted light and red by reflected light.

Obtain a continuous spectrum on a screen as shown above and hold the test-tube of alcoholic solution of chlorophyll against the slit. Dark bands will appear in the red part of the spectrum, and, if the solution is strong, dark bands will also appear in other parts of the spectrum. If desired a direct-vision spectroscope could be used.

Germinate some seeds in the dark and others of the same kind in the light. It will be found that no chlorophyll is present in those in the dark. Chlorophyll has not developed in the absence of light.

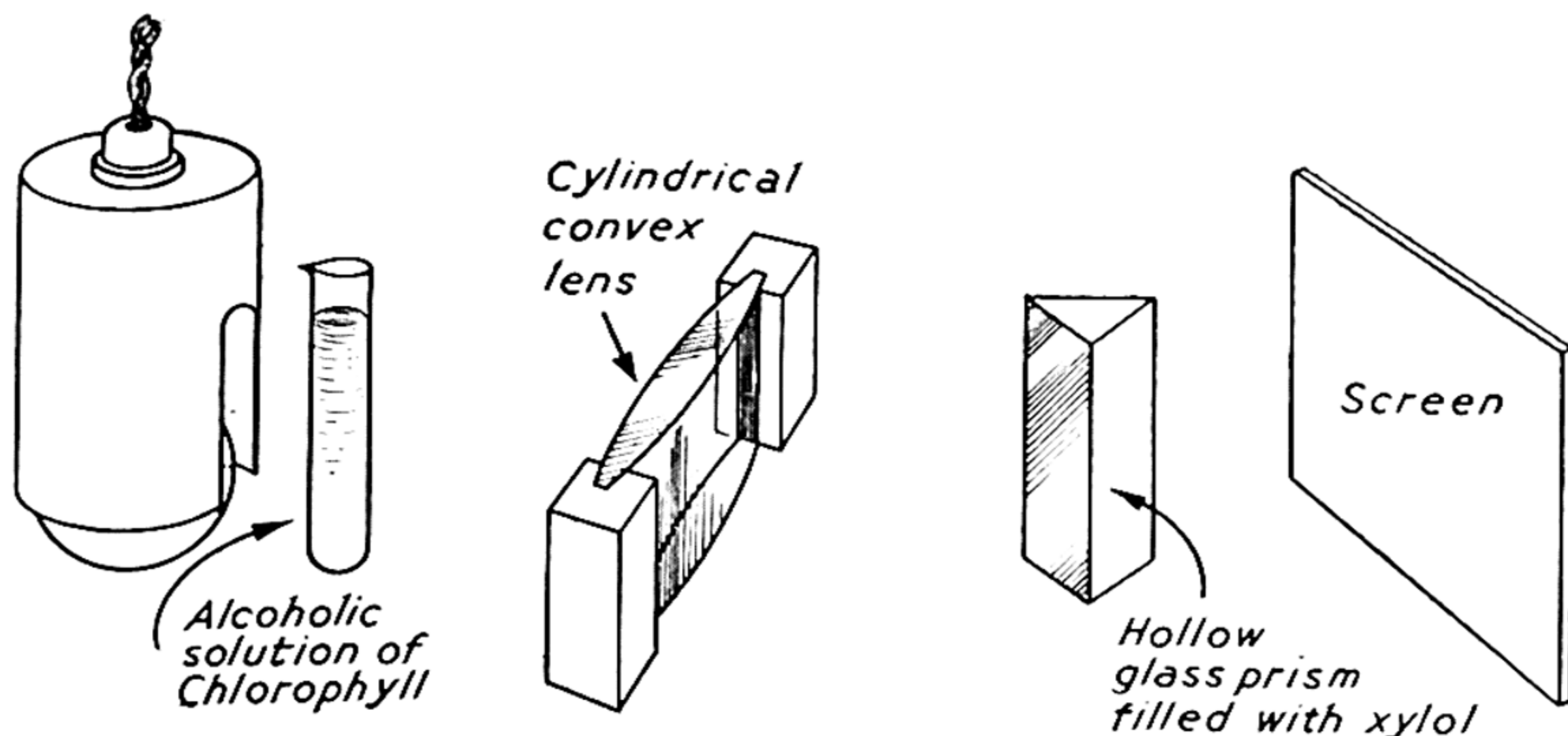


FIG. 87. TO SHOW THAT CHLOROPHYLL CAN ABSORB LIGHT-RAYS

How Simple Plants obtain the Raw Materials for Starch-making

(See Exercise 60, *Everyday Science Topics*, Book II.)

Decolorize a little *Spirogyra* and stain with iodine to show the presence of starch. Examine microscopically.

Water passes from Cell to Cell by means of Osmosis

(See Exercise 63, *Everyday Science Topics*, Book II.)

(1) Examine the root-hair of a pea or a bean. To obtain seedlings quickly germinate seeds on moistened filter-paper in a small dish and keep covered. Within two or three days roots with root-hairs will be found.

Remove a root-hair, mount in water, and examine with microscope.

(2) If desired a collodion bag could be used to show the action of osmosis. A collodion bag is made by pouring a little 4-per-cent. collodion into a large dry test-tube and, by movement of the tube, spreading the collodion evenly round the sides of the tube from bottom to top. Excess collodion should be poured out and the tube rotated until the collodion becomes dry. Then the membrane at the top of the tube should be loosened and the collodion bag separated from the tube by pouring cold water between the two. The bag should be filled with water to test for leaks.

To use, partly fill the bag with sugar solution, tie tightly, and suspend in a beaker of water so that the sugar solution and water are level. Diffusion takes place. Test the water in the beaker for sugar.

How the Plant gets rid of Excess Water

(See Exercise 65, *Everyday Science Topics*, Book II.)

To make cobalt-chloride paper dip filter-paper in a 3-per-cent. aqueous solution of cobalt chloride.

How Complex Plants obtain Carbon Dioxide for Starch-making

(See Exercise 66, *Everyday Science Topics*, Book II.)

(1) To examine upper and under surfaces, see notes on Exercise 55, *Everyday Science Topics*, Book I. If the leaves are allowed to wilt

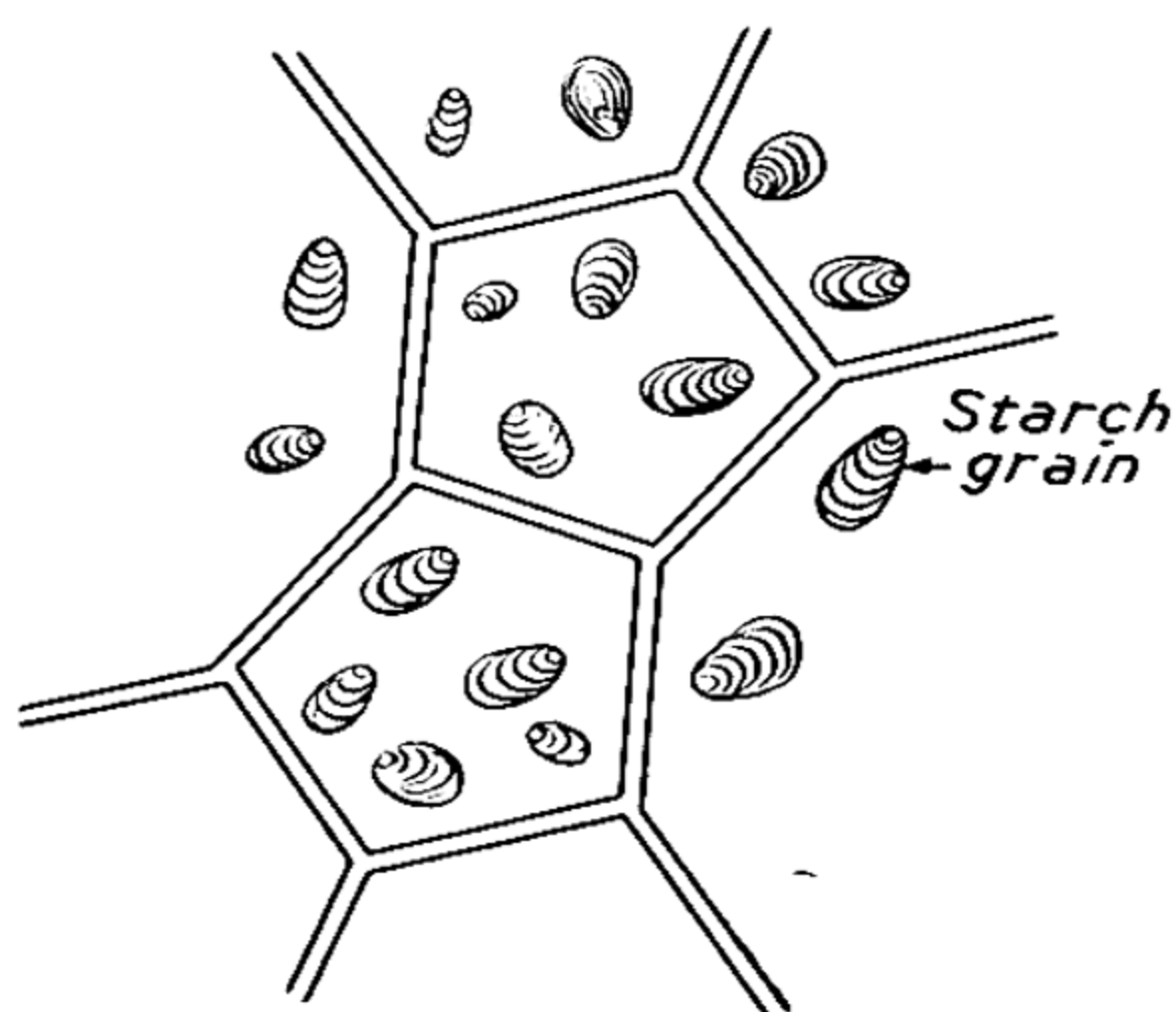


FIG. 88. SECTION OF POTATO, SHOWING STARCH GRAINS

before peeling the epidermal layers can be removed more easily. If a strip of leaf is placed in strong calcium chloride solution for 15 minutes and then examined with the microscope closed stomata can be seen.

(2) To examine transverse section of a leaf, see notes on Exercise 55, *Everyday Science Topics*, Book I. After cutting the section mount in iodine.

(3) Examine leaves of *Elodea* (Canadian pond-weed) microscopically. To do this remove a leaf near the growing tip and

mount it in water. The cells containing chloroplasts will be visible. If the leaf is fresh the movements of the chloroplasts will be seen. If movement is not visible expose the plants to an electric light for an hour, or gradually warm the water in which they are.

(4) That plants store food may be shown by cutting very thin sections of a potato with a sharp razor and mounting the thinnest strip in iodine on a microscope slide and examining with microscope. Cells containing starch grains stained inky-blue will be seen. The sugar made by the leaves of the potato plant is changed into starch by the action of the diastase and is stored in the potato tuber.

Manufacture of Fats and Oils by a Green Plant

(See Exercise 68, *Everyday Science Topics*, Book II.)

Cut with a razor a thin section of a castor-oil seed and examine with microscope or micro-projector. Oil-drops will be seen.

How a Plant uses Mineral Salts

(See Exercise 69, *Everyday Science Topics*, Book II.)

Preparation of culture solutions:

Normal Solution 1000 c.c. distilled water
 1 gm. potassium nitrate
 .5 gm. calcium sulphate
 .5 gm. magnesium sulphate
 .5 gm. calcium phosphate
 .5 gm. sodium chloride
 A trace of iron chloride

Shake up the salts in the water.

Solution without potassium. Replace potassium nitrate by sodium nitrate.

Solution without calcium. Replace calcium sulphate by potassium sulphate and calcium phosphate by sodium phosphate.

Solution without phosphorus. Replace calcium phosphate by calcium nitrate.

Solution without magnesium. Replace magnesium sulphate by potassium sulphate.

Solution without sulphur. Replace calcium sulphate by calcium chloride and magnesium sulphate by magnesium chloride.

Solution without nitrogen. Replace potassium nitrate by potassium chloride.

Solution without iron. Omit iron chloride.

Note. The jars should be sterilized at frequent intervals with boiling water and filled up from stock solutions when necessary. Air should be pumped into the jars about twice a week.

It will be found that phosphates promote fruitfulness, nitrates promote growth, potash improves quality, and iron is necessary for the formation of chlorophyll.

Amæba

(See Exercise 71, *Everyday Science Topics*, Book II.)

(1) To prepare for microscopic examination, see notes on Exercise 59, *Everyday Science Topics*, Book I.

(2) Make a hay infusion by slowly heating a little chopped hay in water until it boils.

Add pond-water when the infusion has cooled and allow bacteria to develop.

Stain the bacteria by adding a very little neutral red to the hay infusion and supply amœbæ with the coloured bacteria.

Observe the capture of the stained bacteria by amœba, and notice that the contents of the food vacuole change from red to yellow, proving that the acid contents become alkaline as digestion proceeds.

Hydra

(See Exercise 72, *Everyday Science Topics*, Book II.)

(1) Specimens should be obtained from ponds by gathering large quantities of weeds and placing them in pond-water in an aquarium.

Examine the weeds and sides of the aquarium for hydra, which will be visible to the naked eye.

(2) To mount, place hydra in a drop of water in the centre of a microscope slide and cover with a cover-slip resting on broken pieces of another cover-slip, to prevent the animal from being crushed.

(3) Place a little 1-per-cent. solution of acetic acid under the cover-slip, taking care not to allow any to flow on top of the cover-slip. By means of a piece of blotting-paper held at the opposite side of the cover-slip draw the acetic acid through. The tentacles become irritated by the acid, and they eject their poison stinging cells which normally operate during food capture.

(4) Observe hydra feeding on water-fleas or Cyclops.

Earthworm

(See Exercise 73, *Everyday Science Topics*, Book II.)

(1) Earthworms may be found in large numbers, without troubling to dig for them, if the grass of lawns is examined at dusk, when the earthworms emerge partially from their burrows, or they may be brought to the surface of the soil during the day by sprinkling with weak mustard solution.

(2) To kill earthworms for dissecting place in hot water, hot 20-per-cent. salt solution, chloroform vapour, or methylated spirit.

(3) Suitable dissecting-mats may be made by cutting up thick cork sheets (a bath-mat from one of the cheap stores) into six-inch squares and weighting them round the edges with lead. Paraffin wax melted and poured into dishes to solidify serves equally well, but it will need to be remelted and reset occasionally. White enamel pie-dishes form suitable dissecting dishes.

(4) Earthworms may be studied easily if placed in a wormery, which consists of a box about 12 in. high, 12 in. long, and 2 in. wide, with the largest two sides replaced by glass. The box should be filled with layers of different-coloured soils—e.g., leaf-mould, sand, clay, loam, limey soil, and chalky soil. Keep the soil slightly moist, cover the glass sides with brown paper and the worms may then burrow against the glass, and the construction of the burrow may then be studied. Place small cubes of different kinds of food—e.g., turnip, carrot, onion—and some decaying leaves on top of the soil in order to discover the food eaten by the earthworm.

(5) Remove a nephridium, or 'kidney,' from an earthworm and examine microscopically in a drop of salt solution. These structures are composed of white tubes, and they are found in pairs in each segment. The cilia inside the tubes can be seen beating. They gather up the waste liquid-matter from the body and pass it outside through small openings.

Daphnia

(See Exercise 74, *Everyday Science Topics*, Book II.)

(1) Examine *Daphnia* in a live box or animalcule trough, as described in notes on respiration in water insects.

(2) Collect *Daphnia* and other small pond creatures in the following way.

By means of a jam-jar wired to a stick collect samples of pond-water and pour it through a concentrating bottle in order to collect the largest quantity of specimens in a minimum amount of water. The concentrating bottle consists of a screw-top jar with holes punched in the lid and a tin funnel soldered through the centre. A piece of fine muslin is stretched over the jar before the lid is screwed on. Excess water passes through the muslin and out of the holes in the lid.

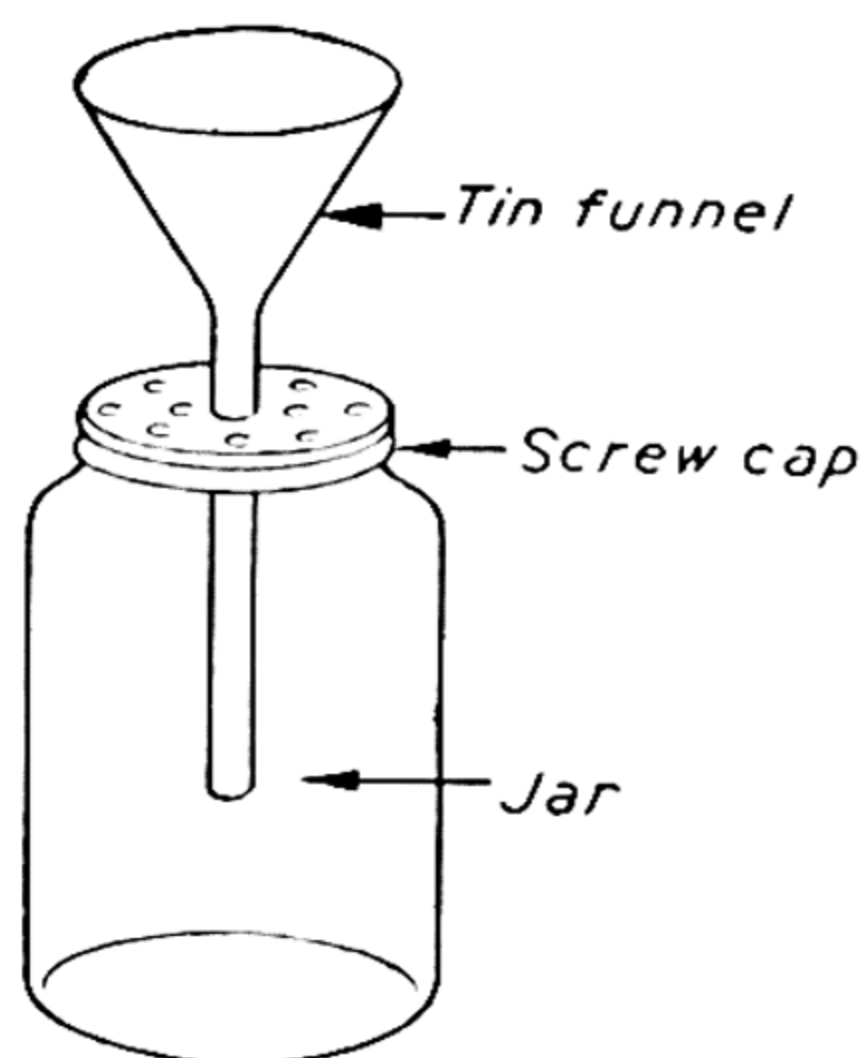


FIG. 89. CONCENTRATING BOTTLE

Frog

(See Exercise 75, *Everyday Science Topics*, Book II.)

(1) Kill the frog with chloroform vapour or ether, but do not pour the chloroform directly on to the animal. Place the frog in a box with two holes in the lid and suspend a pad of cotton-wool soaked in chloroform through one hole, thus allowing the frog to breathe both air and chloroform.

When the animal has been anæsthetized close both holes and so kill the animal painlessly.

(2) After the frog has been dissected to show the digestive system, the method of excretion of waste products could be dealt with and the kidneys, ureter, and urinary bladder pointed out.

Mammals

(See Exercise 77, *Everyday Science Topics*, Book II.)

(1) To prepare the skull of a rabbit simmer the head in hot water and remove the flesh.

Remove the grease by soaking in a fat solvent such as chloroform, then bleach in a dilute solution of hydrogen peroxide.

Examine the joint between the upper and lower jaw. This joint allows the jaw to move backward and forward to facilitate the grinding of hard food, a movement impossible in a human being.

(2) To dissect the rabbit to show its digestive system fasten the rabbit down on its back on a dissecting-board, using nails or large dissecting-pins.

Cut through the skin along the middle line of the body, separate the skin from the underlying tissue, and fasten back or remove the skin entirely.

Cut through the middle line of the body wall and continue the cuts outward towards each limb, then pin out. Notice the diaphragm and the organs of the abdomen.

Ligature the gullet by tying fine string tightly across it and cut it across above the ligature. Ligature the rectum in the same way and cut below.

Double ligature the portal vein just before it enters the liver, and cut between the threads.

Remove the food-passage and spread it out. Notice the cæcum ending in the appendix, at the junction of the small and large intestine.

The cæcum is necessary for the digestion of cellulose, of which vegetable food largely consists. No vertebrate animal produces an enzyme for the digestion of cellulose, so in the rabbit the food is side-tracked into the cæcum to undergo bacterial digestion. In man there is only a vestigial cæcum, so cellulose cannot be digested at all. Foods containing cellulose act as roughage, pushing out waste food from the intestine and so preventing constipation.

Note. The kidneys and urinary bladder should be pointed out at this stage and their work outlined.

(3) Obtain a pig's stomach and examine inner surface with a lens. Notice the openings of the gastric glands. They appear as numerous little hollows.

(4) Obtain a sheep's kidney from a butcher and examine. Identify ureter, renal artery, and renal vein. Blood enters the kidney by means of the renal artery and leaves by the renal vein. The ureter carries urine from the kidney to the bladder.

Make a longitudinal section through the kidney and observe.

Digestion in Man

(See Exercise 79, *Everyday Science Topics*, Book II.)

Pancreatic juice may be obtained by using Benger's Pancreatic Extract or by preparing it as follows.

Obtain from a butcher a pancreas (sweetbread) from a pig or sheep. Cut it up finely and allow it to soak in a 1-per-cent. solution of sodium carbonate. Pour off the liquid and add a drop or two of chloroform to prevent bacterial action.

Many manufacturers of different types of foods issue charts and booklets. Toothpaste manufacturers issue charts and books about the teeth.

Valuable help can be obtained from:

The Food Education Society, 29 Gordon Square, London, W.C.1.

The National Milk Publicity Council, 33 Gordon Square, London, W.C.1.

Publications of the Central Council for Health Education, Tavistock House, Tavistock Square, London, W.C.1. (Full details of these are given in their *Health Education Year Book*.)

Philip's Charts:

"The Human Factory"

"Vitamin Values of Foods"

"Diseases resulting from lack of Vitamins"

Bacon's Charts of the Human Body.

Further Information

The following books, details of which are given in Chapter VII, contain further information about this topic:

HART-SMITH, J., AND E. M.: *A First Book of Home Science*.

LITTLE, W. B.: *Science and Health*.

LITTLE, W. B.: *Science in the Home*.

ROBINSON, C. L.: *The Science of the Home*, Book III.

WHIPPLE, A. H.: *Hygiene of the Home*.

See also pp. 75-114 of *Everyday Science Topics*, Book II.

Films

Digestion (16 mm., sound or silent, coloured, 3 reels) (G.B. Film Library).

Feeding-time at the Zoo (16 mm., sound and silent, 1 reel) (G.B. Film Library).

Food and Growth (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(A feeding experiment with white rats, actually carried out in a classroom, demonstrates the food-value of milk as compared with coffee or sweets.)

Food, Digestion, and Air (16 mm., silent, 1 reel (12 min.)) (Food Education Society).

(The strain of a heavy meal on the digestive organs is indicated by animated diagrams which reproduce the process of digestion. A more suitable meal; importance of exercise.)

- How Plants feed* (16 mm., sound and silent, 1 reel) (G.B. Film Library).
Milk (16 mm., silent, 1 reel) (G.B. Film Library).
Photosynthesis (16 mm., sound and silent, 2 reels) (G.B. Film Library).
The House-fly (16 mm., sound, 1 reel) (Army Kinema Corporation).
The Nutrition Film (16 mm., silent, 1 reel (free)) (British Gas Council).
 (Illustrates the importance of nutrition, with commentary by Professor Julian Huxley.)
Your Children's Teeth (16 mm., sound, 2 reels) (Central Film Library).

Film-strips

- A Balanced Diet* (Visual Information Service).
Carbohydrates and the Calorie (Common Ground, Ltd).
Clean Milk (Visual Information Service).
Fats and Proteins (Common Ground, Ltd).
Food and Health (Common Ground, Ltd).
Nutrition (Army Kinema Corporation).
Respiration and Digestion (Newton and Co., Ltd).
The Teeth (Newton and Co., Ltd).
Vitamins and Mineral Salts (Common Ground, Ltd).

(O) Clothing

Very little thought seems to have been given to the effect of clothing on health. Throughout the ages, since man first started wearing clothes for adornment, very little time seems to have been devoted to the study of the effect of clothes on the human body.

Skin that has been freely exposed to sun and air is smooth, sleek, elastic, and good to look at; the skin of a person that has been starved of sun and air is pallid, dry, rough, pimply, inelastic, and an eyesore. This should induce any self-respecting person to seek the remedy. Hence the importance of this topic in the Secondary School.

Samples of the various textiles and raw materials used for making clothing, together with samples of the many different types of manufactured materials, can be obtained from manufacturers.

To demonstrate the Properties of Textiles and Fabrics

Using the samples of textiles provided by manufacturers, numerous interesting experiments can be carried out to demonstrate their properties. (See Exercise 83, *Everyday Science Topics*, Book II.)

Another important test which should be carried out with textiles is the flame test. Wool and all animal fibres swell up and smoulder away with little or no flame, forming a black bead-like ash, and emitting a characteristic smell like burning horn.

Silk burns like wool, but gives no smell. Cotton, being practically

all cellulose, breaks into a bright flame and burns rapidly away. Cotton fibres will withstand temperature up to 300°F. without injury.

The relative strength of fibres can be tested by using the apparatus illustrated in Exercise 83. About half a dozen fibres twisted together should be used for each test.

A comparison of the breaking loads will show that the relative strengths are: silk, 100; linen, 60; cotton, 40; artificial silk rayon, 25; worsted, 20.

Valuable information on cellular clothing can be obtained from the Cellular Clothing Company, Ltd, 465 Oxford Street, London, W.1. Their booklet *How to become Healthy, Wealthy, and Wise* contains a description of an experiment with four bottles filled with water, all of the same temperature, and a thermometer in each. The bottles are wrapped in different materials—wool, silk, cotton, and Aertex. After the bottles have been left for some time the results prove that the Aertex-covered bottle sustains its original temperature most effectively.

The effects of wearing damp clothing can be demonstrated by wrapping a piece of fabric, moistened in water, round the bulb of the thermoscope illustrated under topic (H), "The Vacuum Flask." The rapid cooling causes contraction of the air inside the bulb, and the mercury moves to the left. A piece of moistened fabric wrapped round the bulb of a thermometer causes a rapid fall of temperature.

A. H. Whipple's book *Hygiene of the Home* contains three helpful chapters giving details of several useful experiments on this topic, and valuable information and help can usually be obtained from the Textiles Departments of Technical Colleges in Yorkshire and Lancashire.

Weight of Clothing

During the summer months it is instructive to compare the weights of a boy's and a girl's clothing. This can usually be arranged while classes are in the gymnasium. The whole of the clothing worn by a boy should be weighed in the laboratory, and this weight will generally be found to be five or six times as great as the weight of a girl's clothing.

Dust in Clothing

The dust usually contained in boys' clothing can be shown by running a vacuum cleaner down the back of a boy's coat. The dust-bag of the cleaner should be removed, and the dust contained in the coat can be seen emerging from the opening which leads into the dust-bag.

Temperature and Humidity under the Clothing

During hot weather the temperature under the clothes should be measured with a clinical thermometer. Arrangements should be made for a boy and a girl to do this under the same conditions. The temperature under the boy's clothing will usually be 5 to 10°F. higher than the temperature under the girl's clothing. If a small paper hygrometer is available the relative humidity under the clothing can be compared. It is always much higher under a boy's clothing, especially if he is wearing a collar and tie and long trousers.

Are the Ultra-violet Rays penetrating the Clothing?

A boy and a girl during the summer months should be allowed to place a piece of light-sensitive paper next to the skin under the clothing. This should be done in a dark room. They should then stand in the daylight for a given time. In the case of the girl it will usually be found that light rays penetrate to the skin, but in the case of the boy they do not penetrate at all.

Very little of a truly scientific character seems to be known of the behaviour of fabrics under wearing conditions. The Textile Institute Conference, held at Southport in June 1937, had this subject as its chief topic.

Further Information

The following books, etc., details of which are given in Chapter VII, give further information on this topic:

ADCOCK, K. J.: *Leather*.

BEAN, H. E.: *Everyday Science*, Book I.

CHAMBERLAIN, J., AND QUILTER, J. H.: *Knitted Fabrics*.

DONALD, T. H. (Editor): *Our Manufacturing Industries*.
Health Education Year Book.

HEDDEN, E. M.: *Science in Housecraft*, Book II.

HOOPER, L.: *Silk*.

HUNTER, J. A.: *Wool*.

KERR, J.: Newsholme's "*School Hygiene*."

LAMBERT, H. G., AND ANDREWS, P. E.: *Heat*.

LITTLE, W. B.: *Science and Health*.

MOORE, A. S.: *Linen*.

PORTER, C.: *School Hygiene and the Laws of Health*.

STEVENS, A. B.: *Textile Bleaching*.

STEVENS, H. P., AND W. H.: *Rubber*.

WHIPPLE, A. H.: *Hygiene of the Home*.

WILLIAMS, J. G.: *Textiles on Test*.

Wool: a Study of the Fibre, issued by the Empire Marketing Board.

See also pp. 115-123 of *Everyday Science Topics*, Book II.

Films

Cotton Goods (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Energy from Sunlight (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Flax to Linen (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Silk (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Woollen Goods (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(P) Seeing*The Action of the Eye*

The action of the eye can be demonstrated by using an old plate camera with a ground-glass focusing-screen. Suitable cameras can often be obtained from sale-rooms. The pupils should observe how the lens forms an image of a well-illuminated object—say, a window. They will see that the image is inverted and how a definite distance between the lens and the screen gives a clear image of an object in a certain position. If the distance between the camera and the object is varied, the distance between the lens and screen in the camera has to be varied to give a clear image. The camera should be dismantled to show its construction. If a camera is not available the apparatus illustrated in Exercises 92 and 94, *Everyday Science Topics*, Book II, may be used.

The pupils will realize that to obtain clear images of objects at varying distances from a camera the distances between the lens and the plate must be varied.

The same apparatus may be used to demonstrate how clear images of objects at varying distances can be produced without changing the distance between the lens and the focusing-screen, as in the eye. In this case lenses of different focal lengths are used. Suitable lenses can be obtained from cheap stores.

The apparatus consists of a wooden box about 8 in. by 6 in. by 5 in. with a hole about 1 in. in diameter bored in one end. The lenses fit over this hole and are held in position by three metal clips. In the other end fits a wooden frame holding the ground-glass screen. This can be moved backward and forward inside the box by means of the two pieces of dowelling.

The Construction of the Eye

The construction of the eye in human beings should be described and examined. Large coloured diagrams are very helpful, especially enlarged copies of the simpler line diagrams to be found in some text-books. Six coloured diagrams showing the structure of the eye, printed on a stout Manila sheet 40 in. by 30 in., can be obtained

from Messrs Griffin and Tatlock, Ltd, Kemble Street, Kingsway, London, W.C.2.

Defects of Vision

The apparatus illustrated in Exercise 94, *Everyday Science Topics*, Book II, may be used to illustrate the common defects of vision.

To illustrate long sight a convex lens may be used which produces a clear image of the object, which is in the same position as before,

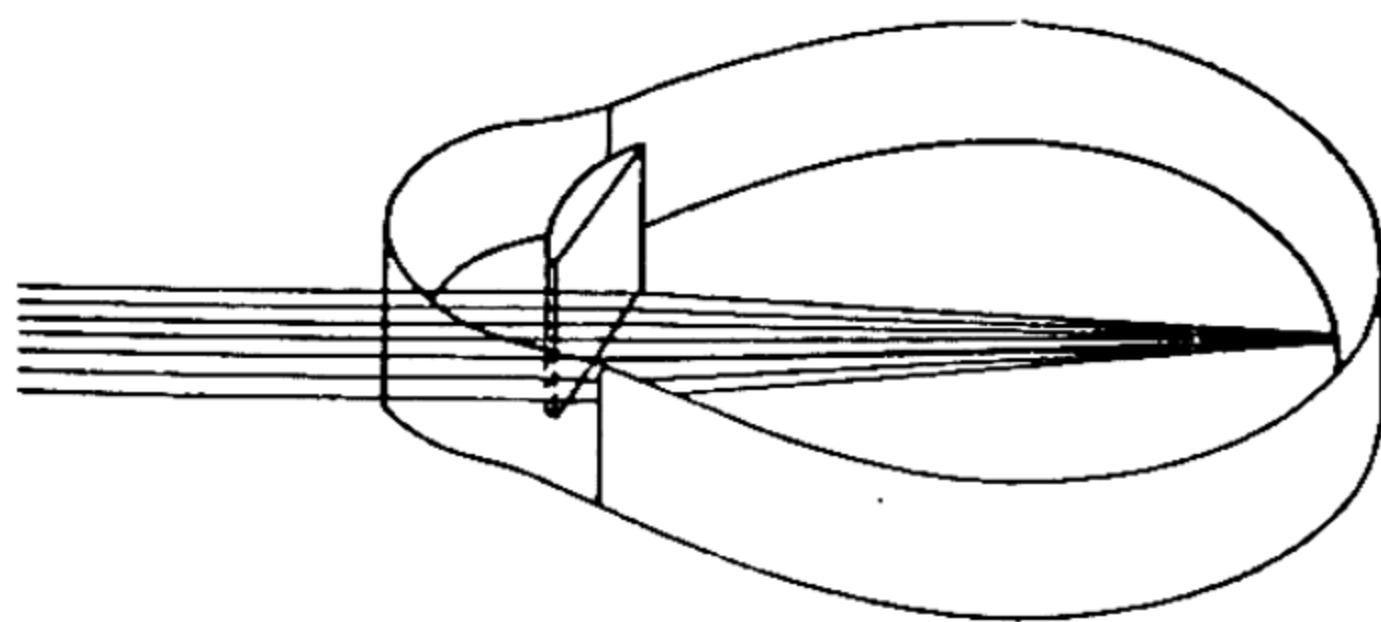


FIG. 90. TO ILLUSTRATE THE PATH OF LIGHT THROUGH THE EYE

behind the position *A* of the screen. A suitable convex lens placed in front of the other convex lens will produce a clear image on the screen in position *A*.

The path of the light through the normal eye and in the short-sighted and long-sighted eye may

be shown by using the light box illustrated in Exercise 100, *Everyday Science Topics*, Book I, together with a strip of white paper or cardboard about 3 in. wide, with a strip of Cellophane in front bent into the shape of the eyeball, as illustrated in Fig.

90. The circular strip is placed on a sheet of white paper placed on the table, and a beam of light from a slit in the light box is allowed to pass through the cylindrical lens, which represents the eye lens. Everything is arranged so that the beam of light produces a clear image of the slit in the light box on the back of the circular strip. This represents the normal eye.

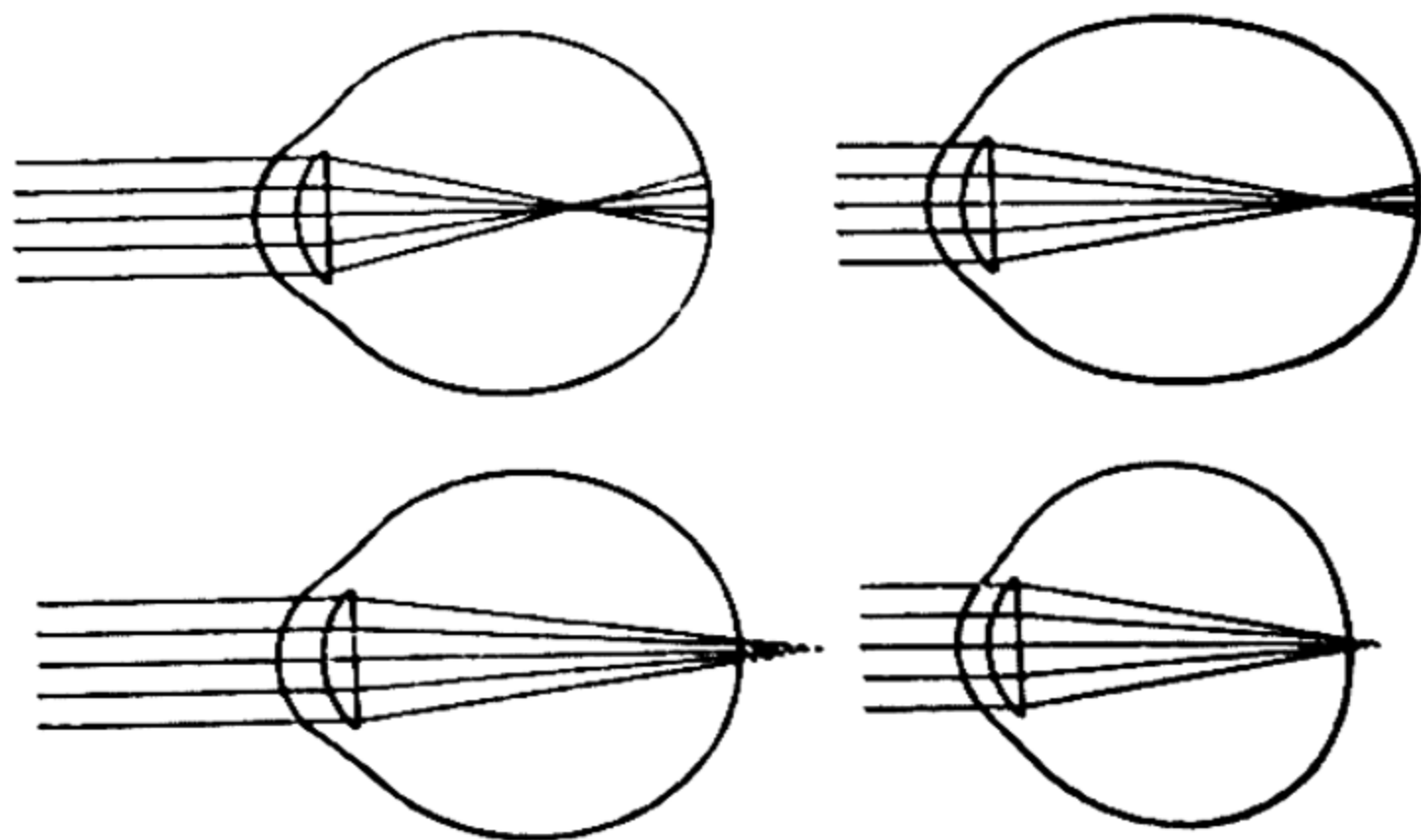


FIG. 91. SHORT SIGHT AND LONG SIGHT

By changing the eye lens, or elongating the eye, as illustrated diagrammatically below, short sight and its correction by using a concave lens in front of the eye can be demonstrated.

Similarly, long sight and its correction can be demonstrated, as illustrated by altering the eye lens, or by shortening the eye.

Further Information

Other experiments and models and further information on this topic are contained in the following books, details of which are given in Chapter VII:

ANDRADE, E. N. DA C., AND HUXLEY, J.: *Things around Us*.

BOKER, T. T.: *Simple Photographic Experiments*.

CROWTHER, J. G.: *Science and Life*.

GIBSON, C. R.: *How Photography came about*.

HADLEY, H. E.: *Everyday Physics*.

JENKINS, J. B.: *Elementary General Science*, Book I.

LITTLE, W. B.: *Science and Health*.

LOW, A. M.: *Popular Scientific Recreations*.

MACDOUGALL, A. T.: *Nature's Mystic Movements*.

MEES, T.: *The Physics of Photography*.

PIGG, J. G.: *The Photographic Instructor*.

PORTER, C.: *School Hygiene and the Laws of Health*.

RAY, C. (Editor): *The Boy's Book of Popular Science*.

SALMON, P. R.: *All about Photography*.

WATKINS, A.: *Photography: Its Principles and Applications*.

See also pp. 124–127 of *Everyday Science Topics*, Book II.

Films

The Eyes have It (16 mm., silent, 1 reel)
(Educational Films Bureau).

Vision (16 mm., sound and silent,
1 reel) (G.B. Equipments, Ltd).

Your Children's Eyes (16 mm., sound,
2 reels) (Central Film Library).

Film-strips

Eyes to see with (Visual Information
Service).

The Human Eye (Newton and Co.,
Ltd).

(Q) The Weather

(I) THE BAROMETER AND AIR PRESSURE

There is such a wealth of material directly or indirectly connected with this topic that it would be impossible to give anything like an exhaustive collection of the material available.

The Simple Mercury Barometer

It is cheaper to buy strong glass tubing for making mercury barometers. Barometer tubes closed at one end are difficult to keep

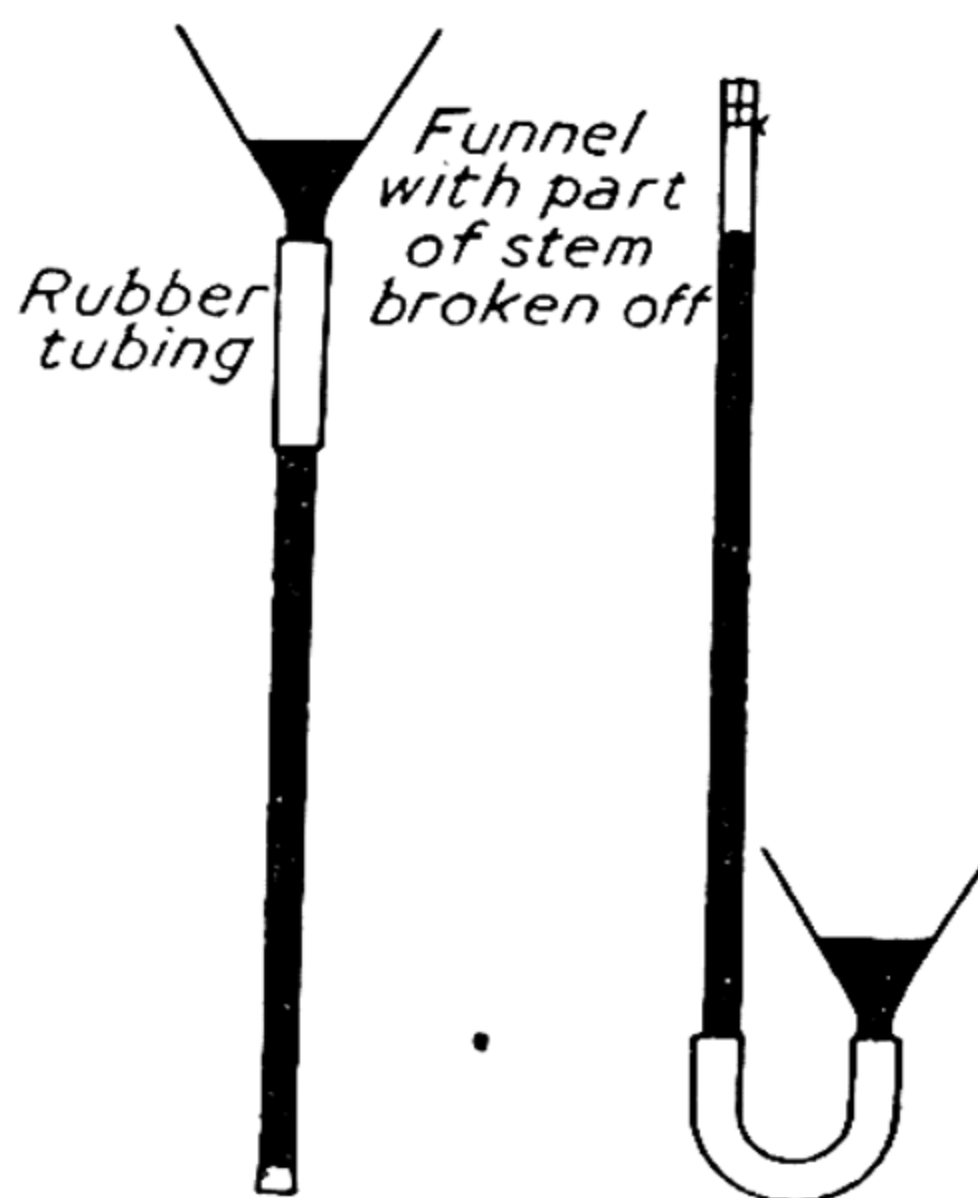


FIG. 92. FILLING A BAROMETER
TUBE

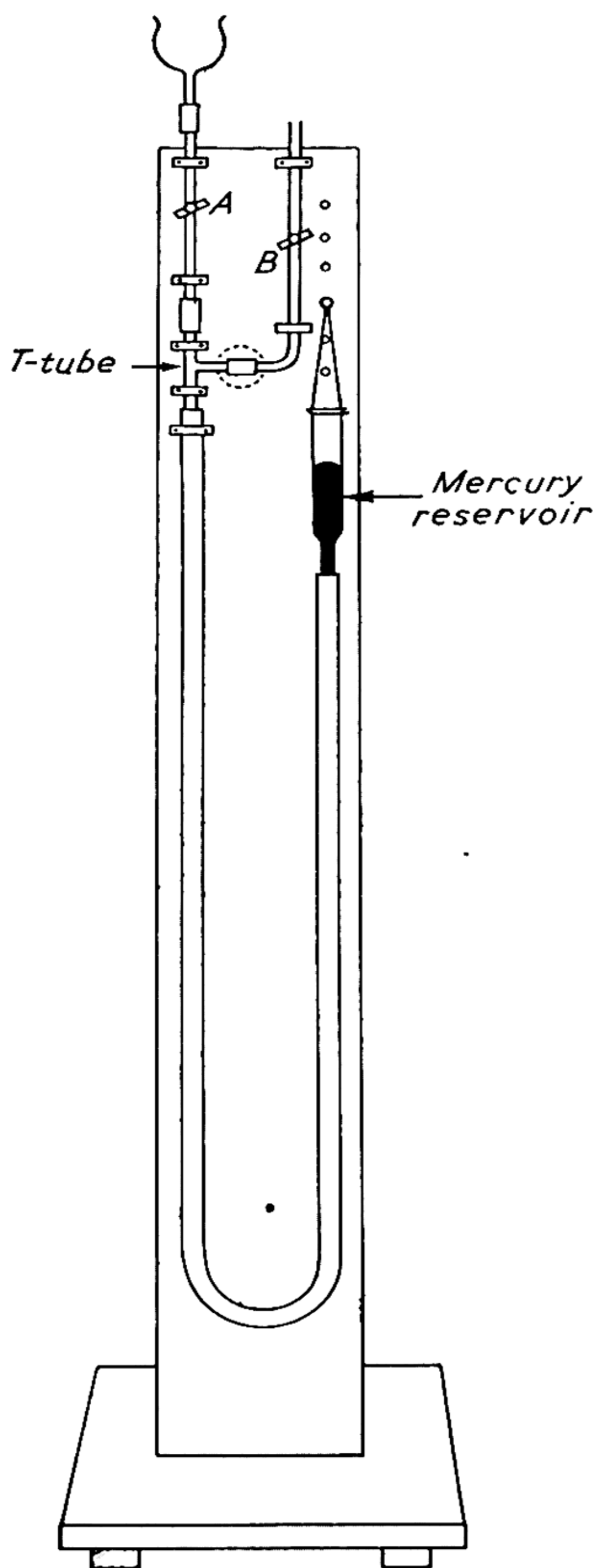


FIG. 93, SIMPLE VACUUM PUMP

clean. The tubing can be cut into suitable lengths, thoroughly cleaned when necessary, and one end can be closed up with a rubber bung, held in position with a piece of wire fixed round a groove made near the end of the tube with a file. A good method of filling a tube is shown in Fig. 92.

The Simple Vacuum Pump

Very good results can be obtained with this apparatus, and expenses have been cut down to a minimum. The action of the pump consists of putting a vacuum into communication with the vessel to be exhausted. A board about 6 in. wide and 48 in. long is mounted on a suitable base 12 in. square, with a supporting piece to prevent wobbling. The most expensive parts of the apparatus are the two glass taps. If suitable taps are not available they can be broken from burettes and connected to the burettes again after use. All the rubber tubing is of the pressure type, and connexions to the glass tubes should be firmly fixed with wire. The mercury reservoir can be made from a test-tube, and is fitted with a wire handle so that it can be hooked in various positions on the board. A further improvement is to connect a large vessel in the form of a tube with a large bulb blown

in it, indicated by dotted line in diagram, between the T-tube and the tap *B*.

To use and test the pump open both taps and pour mercury into the reservoir until it comes just above the tap *A*. The mercury should completely fill the tube, so tap the board gently to remove the air-bubbles. Now close the taps and gently lower the reservoir until it is about 36 in. below the taps, and the mercury will fall until it is at the barometric height, the space above it being a vacuum. Allow the apparatus to stand for a time; if the glass taps leak a little vaseline should be smeared round them.

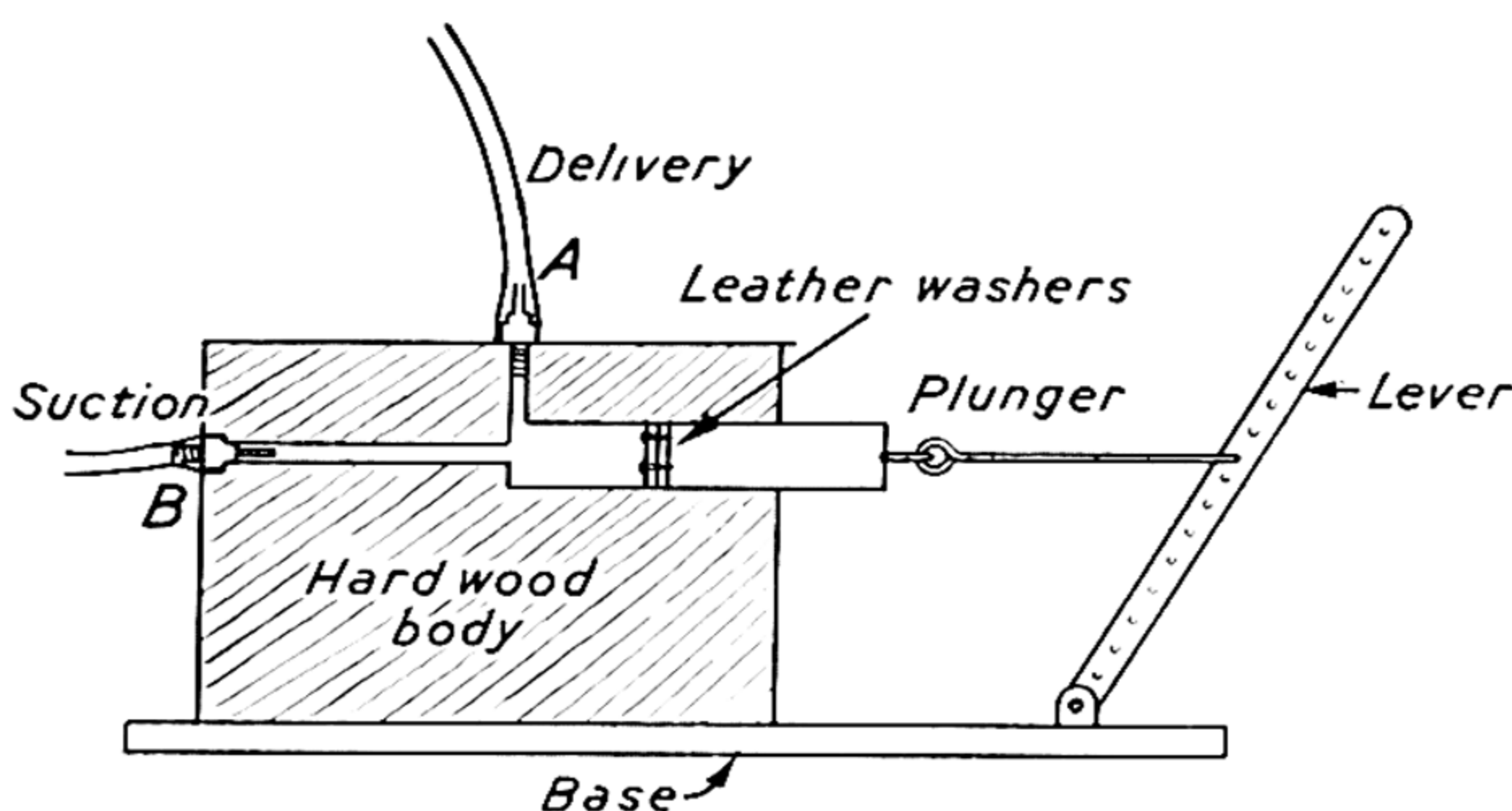


FIG. 94. EXHAUSTING PUMP

The space to be evacuated is connected to the tube *B*; the funnel on *A* is to hold excess mercury if the reservoir is raised too high or too quickly.

To evacuate the space open both taps and raise the reservoir, filling the tubes with mercury to a height of about $\frac{1}{2}$ in. above the taps.

Close *A* and *B* and lower the reservoir until the mercury stands at the barometric height; now open *B*, and this puts the air in the space to be evacuated in communication with a vacuum.

Close *B*, raise the reservoir to its previous height, and open *A*, thus expelling the air from the tube.

Close *A* and repeat until the mercury does not fall on opening *B*.

A Model Exhausting Pump

A and *B* are cycle valves with valve-rubber fixed. Two leather washers are fixed, with a metal plate, to the base of the wooden plunger, and the plunger hole should be well greased. The valves should be carefully sealed in position with a good coating of shellac.

A Meccano strip and brackets may be used for the lever and its supports.

To demonstrate how the variation of air pressure affects the height of the mercury in the barometer the apparatus illustrated in Fig. 3, Exercise 98, *Everyday Science Topics*, Book II, may be used.

Measuring the Pressure of the Air

A method of measuring the pressure of the air using rubber suction-cups is described in Exercise 96, *Everyday Science Topics*, Book II.

Fig. 95 illustrates a simple and fairly accurate method of measuring the pressure of the air. The glass tube should be about 6 in. long and $\frac{3}{4}$ in. in diameter. The piston illustrated is taken from a glass model of a suction and force pump. If such a piston is not available, one can be made from a cylindrical piece of wood cut to the shape illustrated in the diagram and fixed on to the end of a length of iron rod, which has been screwed far enough down so that nuts can be used for fixing.

The piston can be made watertight by wrapping it with string

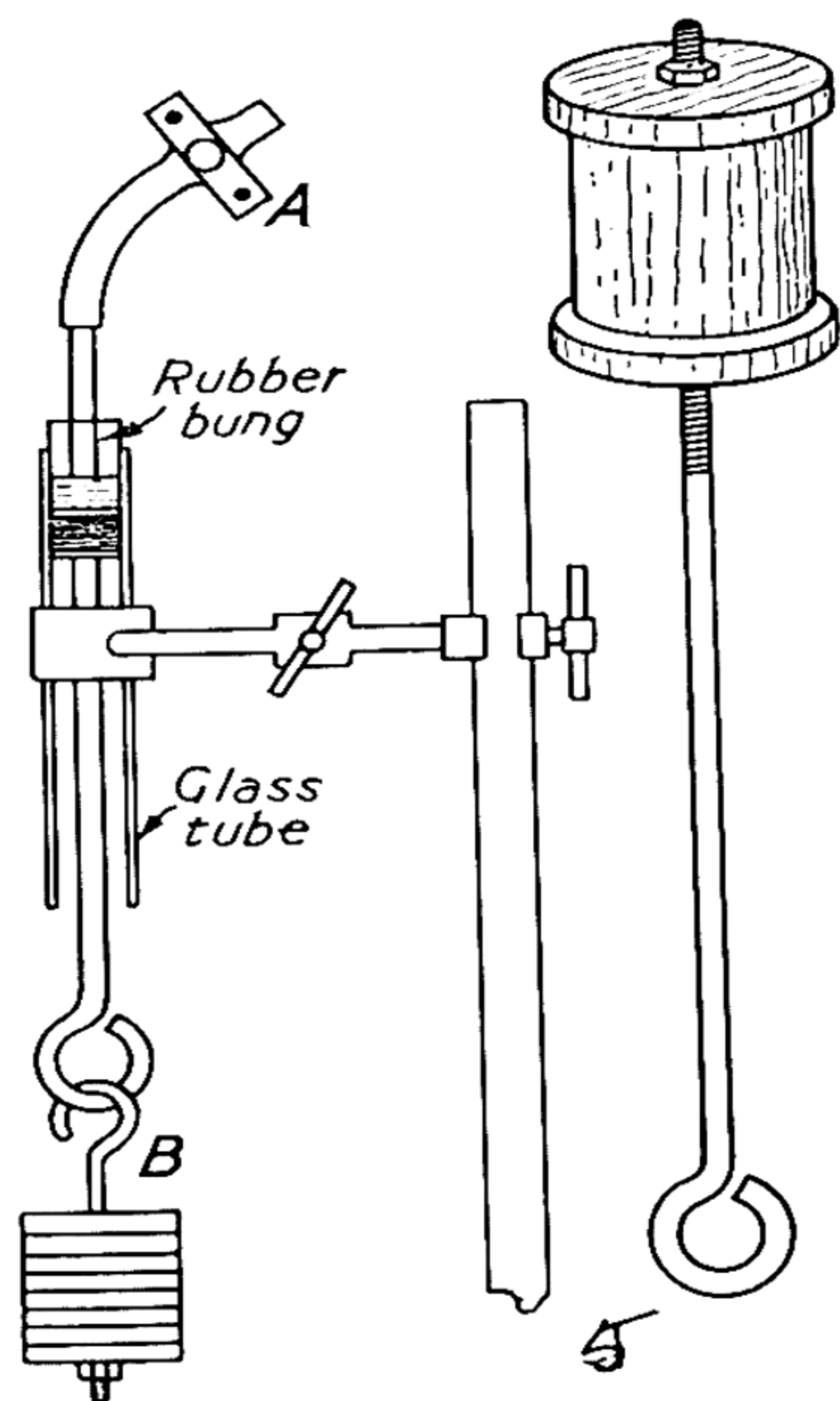


FIG. 95. MEASURING AIR PRESSURE

and immersing in water. It is pushed into the tube as illustrated, a little water is placed above the piston, and a rubber bung with glass tube leading through is pushed in until the water rises above the clip *A* attached to the rubber tube, which is connected to the glass tube. The clip is then closed so that no air remains above the piston. Weights are added on to the hook *B* until the piston begins to move slowly downward.

The internal diameter of the tube being measured, the sectional area of the tube can be calculated, and thus the pressure of the air per square in. can be found. When the piston and water above it have moved so far down the tube the clip *A* can be opened; the air will be heard rushing in, and no weights can be supported.

The fact that air has weight can be demonstrated by weighing an inflated football bladder on a lever balance, then allowing the air to escape and weighing again. Another method, using a worn-out electric lamp, has already been described at p. 82.

Devices worked by Air Pressure

Air-pressure darts can be made in the way shown in Exercise 97, *Everyday Science Topics*, Book II.

Pupils always enjoy making fountain-pen fillers. They can be made by drawing out a length of glass tubing, when melted in a

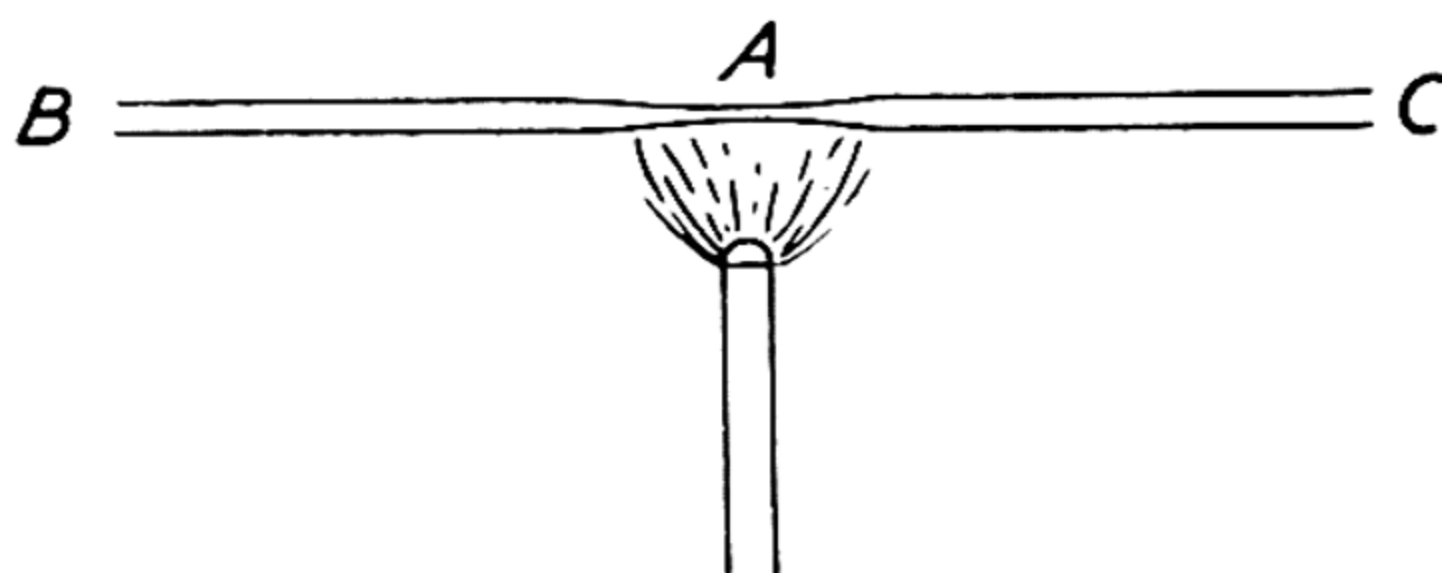


FIG. 96. MAKING A FOUNTAIN-PEN FILLER

batwing or Bunsen flame (Fig. 96). The tube is broken at *A*, and rubber teats are fixed at *B* and *C*.

The Aneroid Barometer and Barograph

These are expensive pieces of apparatus. If they cannot be obtained in the usual way they can often be purchased second-hand from sale-rooms or from Electradix Radios, 214 Queenstown Road, London, S.W.8, or C. Baker, 244 High Holborn, London, W.C.1. The aneroid barometer should have an altitude scale. The catalogues issued by Messrs A. Gallenkamp and Co., Ltd, 10 Clifton Street, Finsbury Square, London, E.C.2, Messrs Griffin and Tatlock, Ltd, Kemble Street, Kingsway, London, W.C.2, and Messrs Reynolds and Branson, Ltd, 14 Commercial Street, Leeds, give full particulars and prices of aneroid barometers and recording barographs.

The complete portable meteorological outfit, including aneroid barometer, thermometer with Fahrenheit and Centigrade scales, maximum and minimum thermometer with magnet, wet- and dry-bulb hygrometer, rain-gauge, and calendar for keeping records, sold by Messrs Gallenkamp is an excellent set for those schools which can afford it. Messrs Gallenkamp will supply a demonstration aneroid barometer, showing movement, and vacuum box, suitable for placing under the air pump, for demonstrating the action.

Fig. 97 shows a model for demonstrating the action of an aneroid barometer. A potted-meat dish stands in a hollow made in a wooden

base. The dish is covered with a piece of balloon rubber, held tightly in position with a piece of wire. The wooden pointer is fixed by means of a nail to the upright piece of wood. The pointer should be free to move up and down, and the end is kept in contact with the rubber sheet by means of a small piece of lead taken from a piece of lead-covered electric cable. The apparatus is placed under

a bell-jar, and increase or decrease of pressure on the rubber sheet is indicated by the pointer.

The Barometer as a Weather Glass

Fig. 98 illustrates a method of making a demonstration wheel barometer with all working parts clearly visible. I was fortunate in being able to purchase for 2s. a second-hand baro-

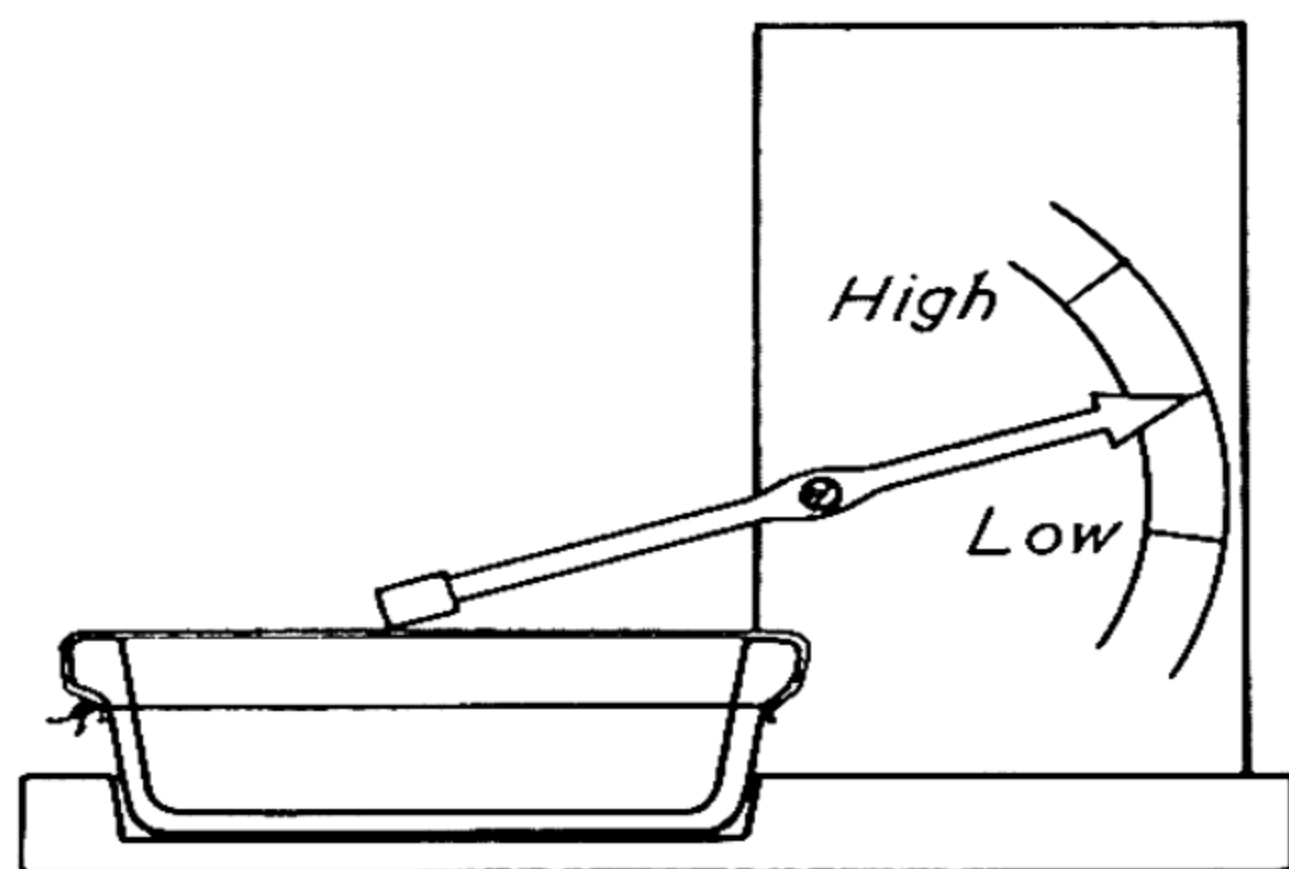


FIG. 97. MODEL ANEROID BAROMETER

meter at a local sale-room. The glass U-tube was broken and the mercury missing, but the dial, pointers, wheels, axles, and bearings were all intact, and were used in making the model illustrated.

There must be many such second-hand barometers in sale-rooms, and, even if a second-hand barometer cannot be obtained, the dial could be made and Meccano wheels and rods, and a little brass tubing used for the other parts.

The wooden stand should be made first. *A* is a barometer tube, *B* a length of rubber tubing, and *C* a short length of glass tubing in which a short length of narrow-bore glass tubing, *D*, will move up and down easily. *E* is a length of glass tubing similar to *D*, but a little longer, to make it just a little heavier. *F* is a length of black cotton which passes through *D* and *E*, and is fixed to them by making knots at the ends. The upper ends of *D* and *E* should be closed with a little sealing-wax. The cotton passes once completely round the grooved wheel *G*.

The tube *A* should be completely filled with mercury until it is just above the level of the rubber tubing in *C*. The tube is then fixed to the upright board, the glass tube *D* placed inside the tube *C*, and the cotton wrapped round the grooved wheel *G*. The level of the mercury in *A* above the level in *C* should be carefully measured, and the pointer *H* fixed into its correct position.

The axle of wheel *G*, to which is attached the pointer *H*, passes

through a short length of brass tubing which has a grooved wheel fixed at one end and a pointer at the other end. This brass tubing has, as bearings, a piece of brass plate on one side and the dial on the other side.

When discussing the measurement of height by means of the barometer, beware of stating that 1 in. fall of the mercury column

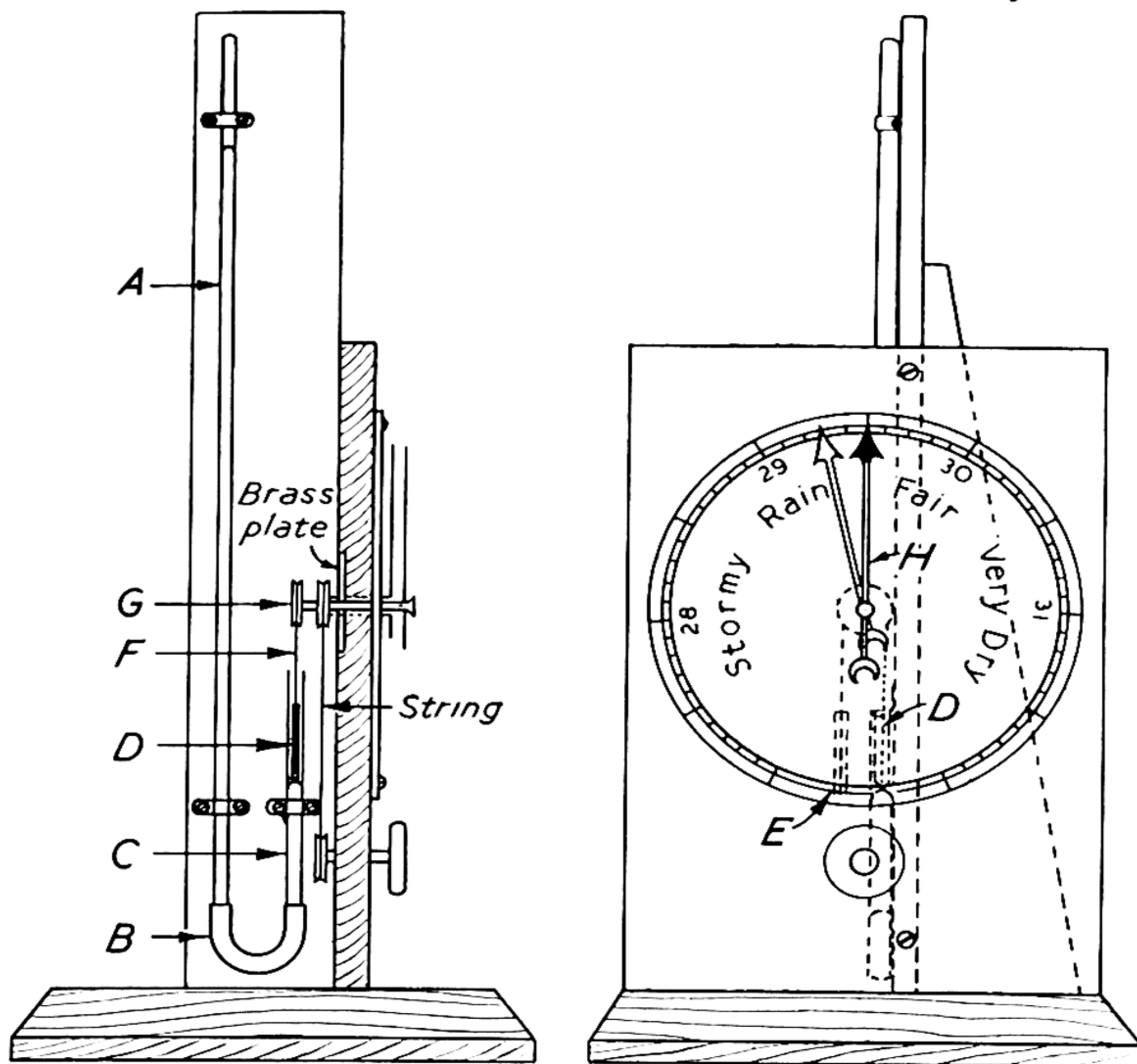


FIG. 98. MODEL WEATHER GLASS

means that the barometer has been raised 900 ft. This rule, often in print, assumes that the air is always and everywhere of the same density, which is far from being the case. At sea-level the air has the whole weight of the air above it. At a height of 10,000 ft. the weight is much less: 900 ft. of air is no longer equal to 1 in. of mercury, and the rule becomes altogether inaccurate. The length of the column of air equal to 1 in. of mercury at various pressures and temperatures can be obtained from altitude tables.

All pupils should be encouraged to read the following books on the Everest Expeditions: *The Epic of Mount Everest*, by Sir Francis Younghusband (Edward Arnold, 1928), and *The Challenge of Everest*, by G. J. Cons (London University Press, 1934). The latter book is intended to be a preparation to *Climbing Mount Everest*, the official sound-film record of the 1933 expedition. Full particulars of the film can be obtained from the Western Electric Company, Ltd, Bush House, Aldwych, London, W.C.2.

An excellent set of slides illustrating the 1921, 1922, and 1924 Everest Expeditions, together with literature, can be hired from Messrs. Newton and Co., Ltd, 72 Wigmore Street, London, W.1.

A second-hand anemometer may sometimes be obtained from Electradix, 214 Queenstown Road, London, S.W.8. Model anemometers are described in *Nature's Wondrous Laws* and *Science in Common Things*, Book I, particulars of which are given below.

The catalogue of meteorological publications issued by the Meteorological Office, and obtainable from the Air Ministry, Adastral House, Kingsway, London, W.C.2, contains details of many excellent publications, including the Daily Weather Report, British Section.

Further Information

Other experiments and models and further information on this topic will be found in the following, details of which are given in Chapter VII:

ANDRADE, E. N. DA C., AND HUXLEY, J.: *Things around Us* ("Science for Seniors," Book I).

BEAN, H. E.: *Everyday Science*, Books I, II, and III.

BRAY, F.: *Elementary Science*, Part II.

CLAXTON, W. J.: *The Story of the Weather*.

FOURNIER, E. E.: *Wonders of Physical Science*.

FREWIN, J. G.: *A New Experimental Science*, Part I.

HADLEY, H. E.: *Everyday Physics*.

HUGHES, A. G., AND PANTON, J. H.: *Elementary General Science*, Book III.

LITTLE, W. B.: *Science and Weather*.

LOW, A. M.: *Popular Scientific Recreations*.

LUKE, F., AND SAUNDERS, R. J.: *Experimental Science in School*, Book I.

MACDOUGALL, A. T.: *Nature's Wondrous Laws*.

MCKAY, H.: *First Steps in Science*, Book IV.

MANFIELD, G. W.: *Practical Science for Seniors*, Book II.

SCARR, W. A.: *Science in Common Things*, Book I.

See also pp. 128-135 of *Everyday Science Topics*, Book II.

Films

Atmospheric Pressure (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Temperature, Pressure, and Wind (16 mm., sound, 4 reels) (Army Kinema Corporation).

(II) RAIN, THE RAINBOW, LIGHTNING, THE SUN, AND
METEOROLOGICAL OBSERVATIONS*Moisture in the Atmosphere: the Rain-gauge*

In every school where meteorological observations are made the *Meteorological Observer's Handbook* should be available. It is obtainable from H.M. Stationery Office, Adastral House, Kingsway,

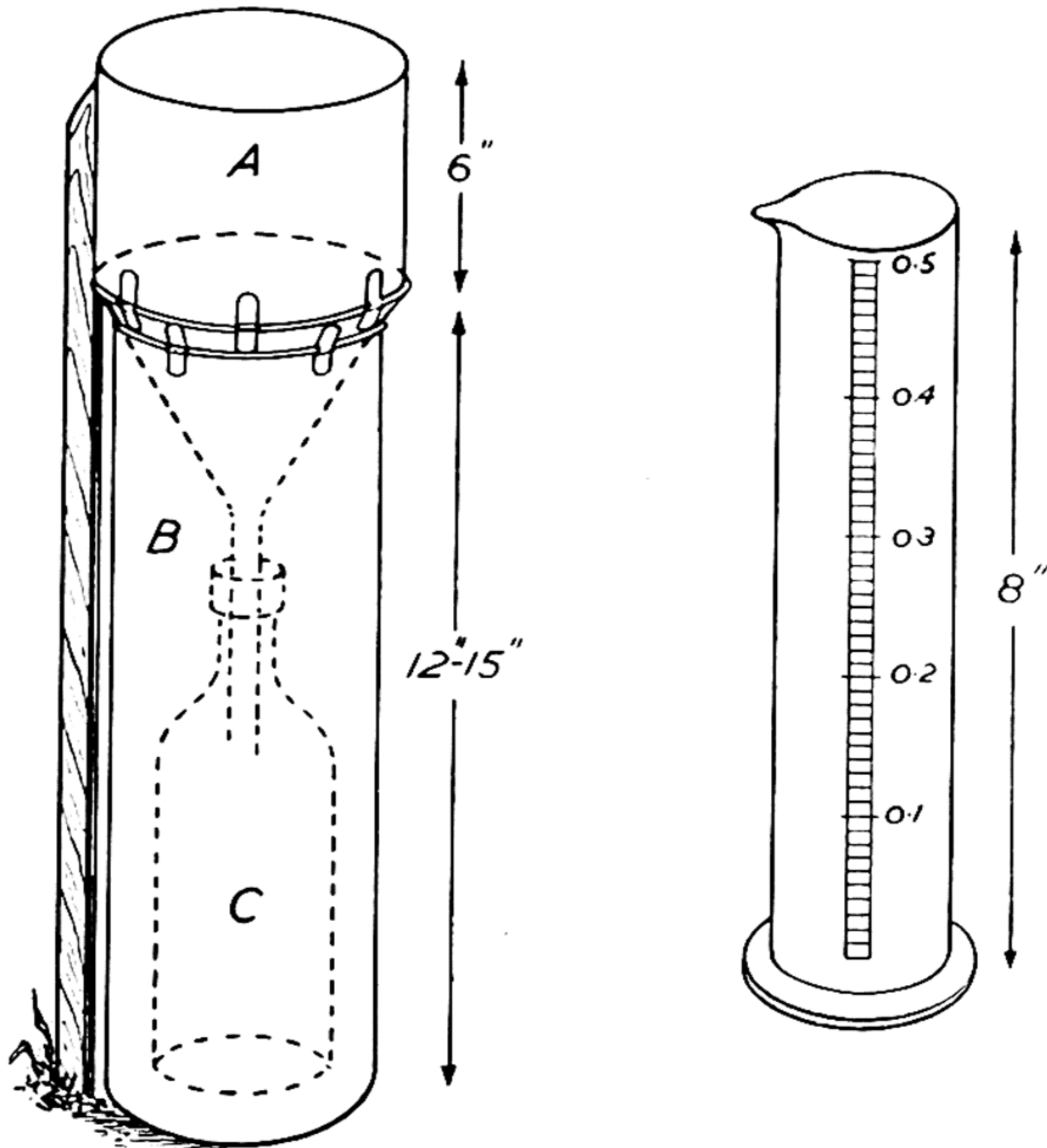


FIG. 99. A HOME-MADE RAIN-GAUGE AND MEASURING-JAR

London, W.C.2. In addition to giving a full description of all types of rain-gauges, methods of exposure and fixing, it also includes illustrations and descriptions of all other meteorological instruments and cloud forms, and much more information which will be of great use in most secondary schools.

An efficient rain-gauge can usually be made by second- or third-year pupils in the metalwork room, and where this is impossible it is not difficult to improvise. Copper gauges are used almost exclusively, on account of their durability, and the diameter of the funnel is usually 5 in. or 8 in. In exposing and fixing a rain-gauge the rim

should be 1 ft. above the surface of the ground, to prevent water splashing into the gauge, and it should be well away from the sheltering effect of houses, trees, bushes, etc.

Since a rain-gauge must measure also the fall of snow or hail, it is important that the sides of the funnel should be vertical for 4–6 in. at the top, otherwise some of the snow and hail, and even some of the rain, may be lost. The gauge should, of course, be firmly fixed, so that it cannot be blown over in a gale. The sketch illustrates how a rain-gauge may be improvised from a tin-plate funnel, two cylindrical tins, and a bottle.

A is the upper part of a cylindrical tin about 5–8 in. in diameter. In cutting this, care must be taken to prevent deformation of the rim. The lower edge may be soldered to the rim of the funnel, which has the same diameter as the tin, or it may be held in position with small pieces of brass soldered to the funnel as illustrated. If the latter method is adopted, the joint should be sealed with insulating tape. Suitable funnels can be obtained for about 6*d.* from any hardware store, and suitable cylindrical tins can often be obtained from confectioners.

B is a cylindrical tin about 12–15 in. tall, with small pieces of brass soldered near the rim to hold the funnel and *A* in a horizontal position. *C* is a narrow-necked bottle. The whole apparatus can be fixed rigidly near the ground with three wooden stakes placed round the gauge and driven about three or four inches into the soil.

When a rain-gauge is improvised in this way it is necessary also to improvise a measuring-jar, so that the depth of rain which has fallen on the area of the opening of *A* may be accurately measured. An ordinary measuring-jar can be used for this purpose. The internal diameter of the measuring-jar should be measured in several places along its length with callipers, and the mean internal diameter can thus be found. The mean diameter of *A* should also be carefully found.

Suppose the diameter of *A* is 6 in., then $\frac{1}{2}$ in. of rainfall on the area of the opening of *A* will have a volume of

$$\pi \times 9 \times \frac{1}{2} = 4\frac{1}{2}\pi \text{ cu. in.}$$

If this volume of rain is poured into a measuring-jar of diameter $1\frac{1}{2}$ in., the depth, *h*, in the jar can be found thus:

$$\pi \times \frac{3}{4} \times \frac{3}{4} \times h = 4\frac{1}{2}\pi,$$

$$\frac{9h}{16} = 4\frac{1}{2},$$

$$h = 8 \text{ in.}$$

A strip of paper should be stuck on the outside of the measuring-jar and marked off as illustrated.

Recording Rainfall

Perhaps the best methods of recording rainfall are those used by the Meteorological Office, and designed by G. J. Symons, founder of the British Rainfall Organization. Form 1114 is a diagram register for one month. Form 1090 is for entry of the daily rainfall in inches for one year. Full instructions for the use of these forms are given on the back of each.

Other registers and forms for the entry of rainfall are: Form 1122, *Mill's Pocket Rain Register* for one year, and Form 1098, postcard for entry of daily rainfall in inches for one month.

All the above are obtainable from H.M. Stationery Office.

The presence of moisture in the atmosphere can be demonstrated by drawing air through a U-tube, *D*, filled with broken glass and phosphorous pentoxide, as illustrated in Exercise 99, *Everyday Science Topics*, Book II.

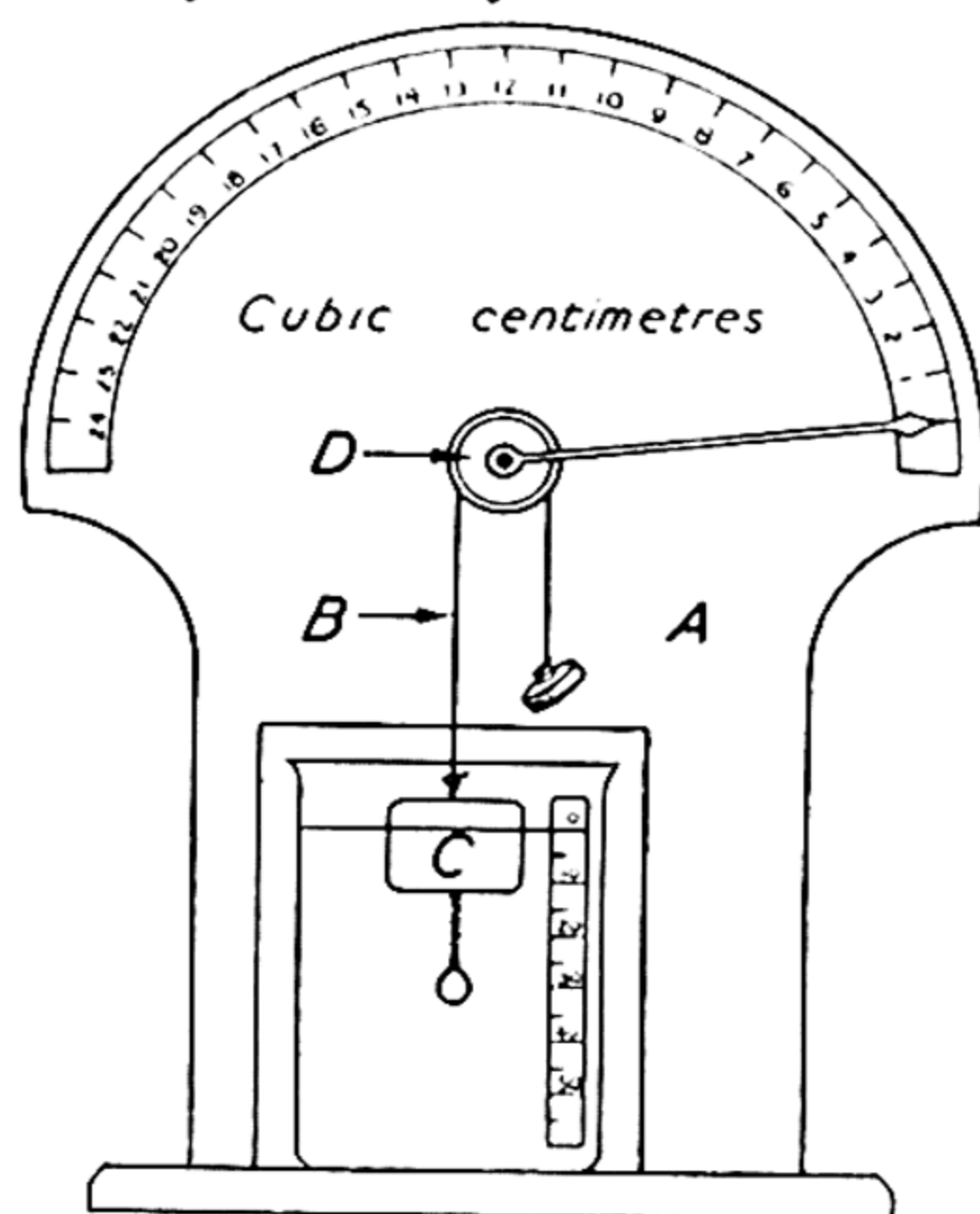


FIG. 100. EVAPORATION GAUGE

Evaporation

This and related phenomena can best be explained by introducing, in a simple way, the kinetic theory—how the heat possessed by a liquid is simply due to the energy of movement of its constituent molecules, and how those molecules, moving most quickly, escape through the surface of the liquid into the air, the liquid losing heat because the molecules left are moving more slowly. The effect of variation of air pressure on the escaping molecules can be mentioned.

The rates of evaporation of equal quantities of water or ether may be compared when placed side by side in a shallow tin and a tall, narrow vessel such as a test-tube. The liquid in the shallow tin will have completely disappeared long before that in the test-tube.

Fig. 100 and the diagram in Exercise 100, *Everyday Science Topics*, Book II, illustrate model evaporation gauges, by means of which the rates of evaporation of liquids under various conditions can be measured.

In the evaporation gauge illustrated here, *A* is a piece of plywood fixed to a wooden base on which stands a glass beaker to hold the liquid. A rectangular piece of the plywood is cut away to allow the beaker to be so placed that the thin cord *B*, with the carburettor float, *C*, at one end and the balancing weight at the other end, may pass over the Meccano pulley-wheel, *D*. The method of attaching the pulley-wheel to the plywood is illustrated in Fig. 101. *E* is a Meccano bush-wheel fixed with three screws to the plywood, *F* is a short length of Meccano rod, *G* is a spring clip, *D* is the pulley-wheel, and *H* is a collar with set screw.

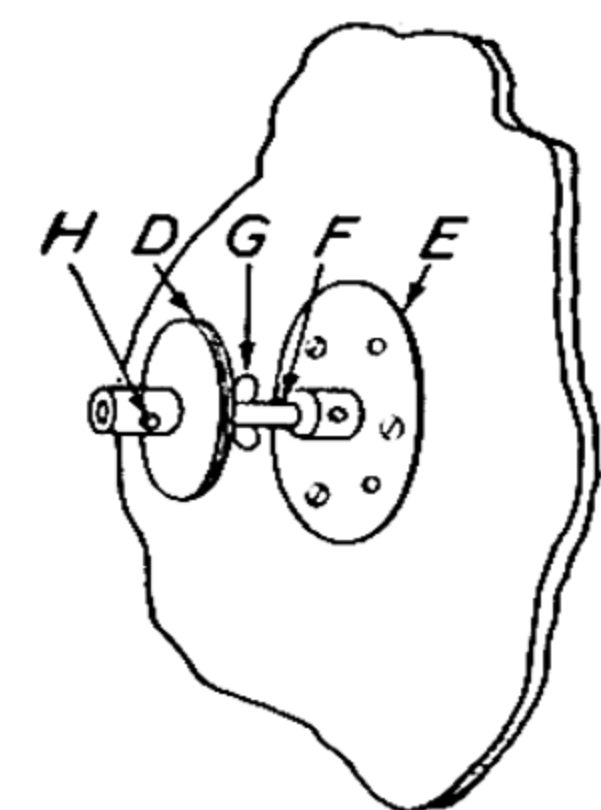


FIG. 101. HOW TO ATTACH THE PULLEY-WHEEL TO PLYWOOD

In the model illustrated it was found, after careful calibration of the beaker, that when 24 c.c. of water disappeared from the beaker, the water-level being first of all marked with a line on the float and as zero on a strip of paper stuck on the outside of the beaker, the pointer moved through 180° . The plywood was then marked off in cubic centimetres as illustrated. The evaporation of a known volume of liquid in a given time could then be observed.

These evaporation gauges have many uses. The rates of evaporation of liquids may be measured in the classroom, in the open air on a calm day and on a windy day, in the sunshine, in the shade, and in a confined space—say, under a bell-jar. The rates of evaporation of water from these gauges indicate the amount of moisture in the air and whether or not rain is likely to fall.

After a continuous spell of dry weather, and in the sunshine, the rate of evaporation of water from the second gauge was 15 c.c. per hour.

A useful reference booklet for teachers is *The Average Monthly Rainfall of the British Isles, 1881 to 1915*, by M. de Carle S. Salter (obtainable from H.M. Stationery Office).

Latent Heat of Evaporation

Some elementary treatment of latent heat should certainly be attempted, on account of the great importance of this phenomena. It is not difficult to get pupils to realize that boiling is simply rapid evaporation, and that during the change an enormous amount of heat is absorbed from a gas flame. To show the heat given up during the reverse change steam may be passed into cold water.

The heat absorbed during the process of evaporation may be demonstrated in many interesting and simple ways. A moistened

piece of muslin may be wrapped round the bulb of a thermometer and a current of air blown across it, a little ether or methylated spirit may be placed on the back of the hand, a wet cloth on the forehead, or moistened cotton-wool round a tin can containing hot water. In the latter experiment the time to cool through a certain range of temperature may be compared with the time to cool through the same range without the moistened cotton-wool.

Where an air pump is available, place some water in a shallow dish and support this on wires over another dish containing concentrated sulphuric acid, the whole being placed under the receiver of the air pump. On reducing the pressure, rapid evaporation will take place from the water. The water vapour will be absorbed by the acid, and evaporation of the water will continue so rapidly that it will freeze.

Cooling produced by Evaporation

The apparatus shown in Fig. 102 may be used to show the cooling produced by the rapid evaporation of ether or methylated spirit. *A* is a small tin about 4 in. high and 2 in. diameter. This fits into a hole about $2\frac{1}{2}$ in. in diameter and $\frac{1}{4}$ in. deep in the piece of wood *B*. Ether or methylated spirit is placed in the tin so that it is about one-third full,

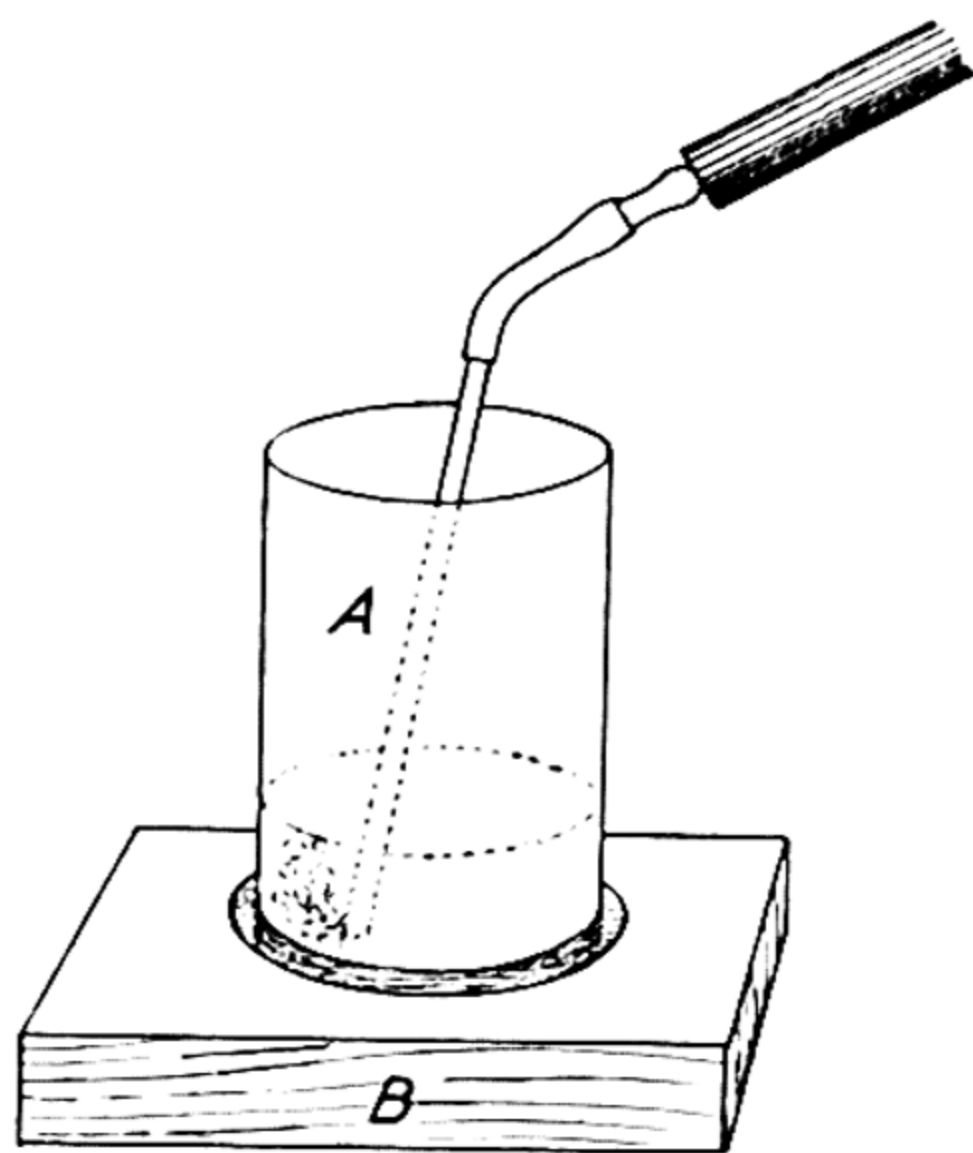


FIG. 102. TO DEMONSTRATE COOLING BY EVAPORATION

and water is placed in the hole in the wood. A current of air is blown through the ether or methylated spirit by means of a glass tube attached, by means of a short length of rubber tubing, to a football adaptor fitted into a bicycle-pump. In about five minutes the water is frozen and the tin becomes attached to the wood.

Butter and Milk Coolers

The diagrams in Fig. 103 illustrate butter and milk coolers for use in hot weather. These are useful applications of the cooling produced by evaporation. The water passes slowly through the pores of the plant pots and evaporates continuously from the outside, thus cooling the pots, the water, and the butter and milk.

Distillation

When discussing the moisture in the atmosphere the seas are mentioned as the chief sources of this moisture. Pupils may ask

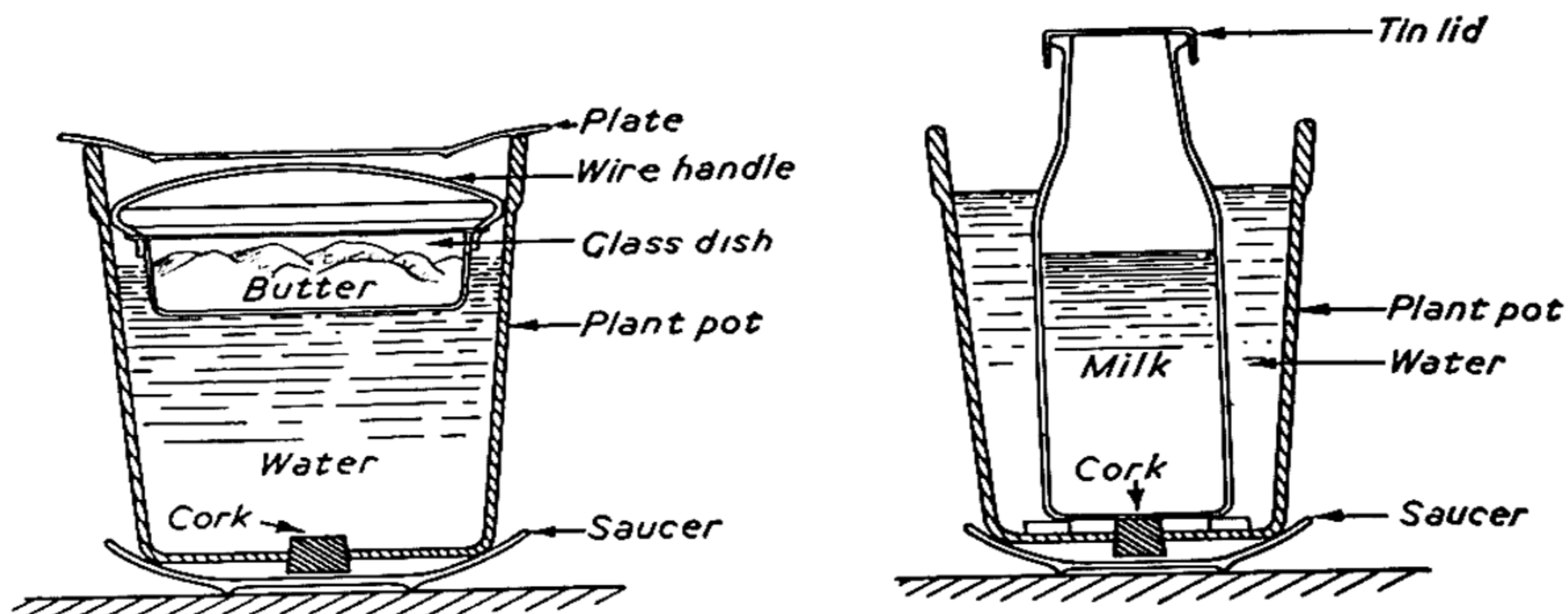


FIG. 103. BUTTER AND MILK COOLERS

why the moisture in the air is not salty, and some discussion and experiments on distillation may be necessary.

Fig. 104 illustrates a model distillation apparatus which may be used for these experiments, and as a source of supply of distilled water required for the accumulators in the laboratory, and for other purposes. *A* is a 2-lb. treacle tin in which the salty or other impure

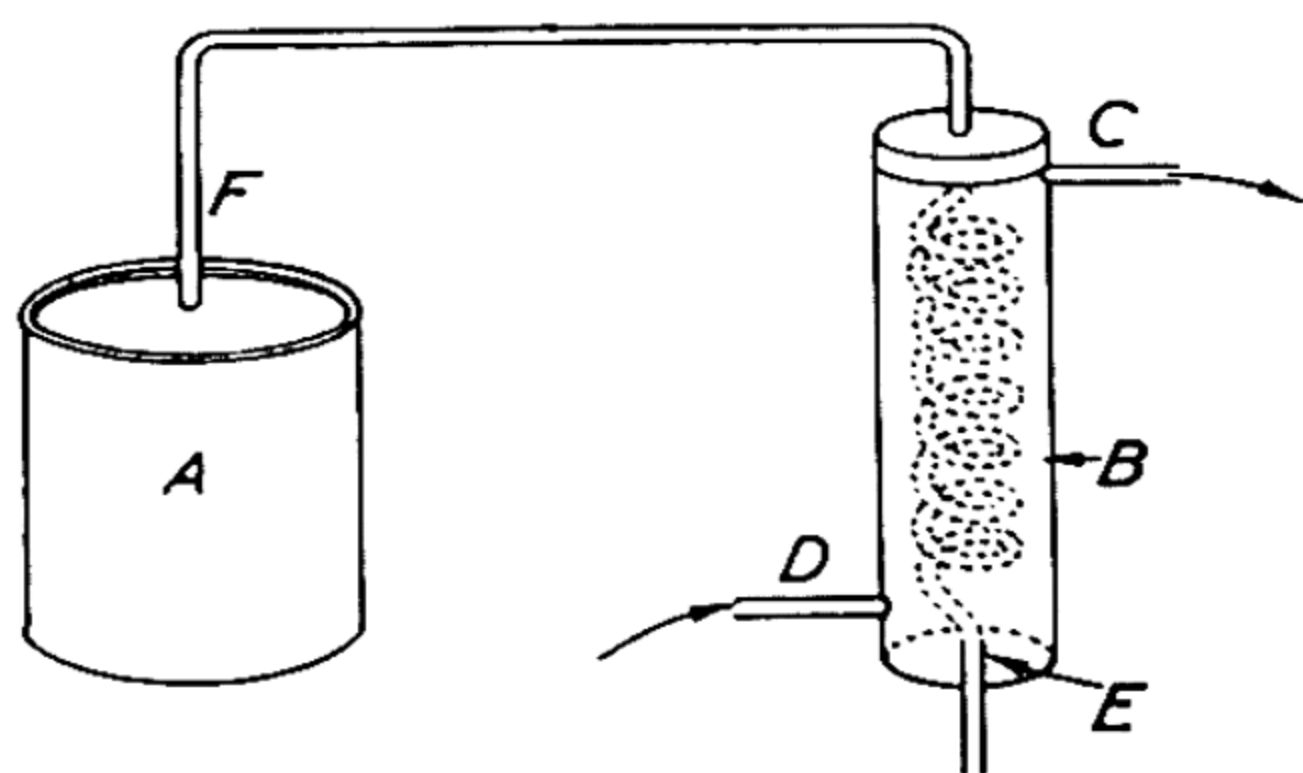


FIG. 104. DISTILLATION APPARATUS

water may be placed. About 6 ft. of a 7-ft. length of copper tubing $\frac{1}{4}$ in. in diameter is pulled into spiral form round a cylindrical piece of wood held in a vice. *B* is a cylindrical tin with short pieces of copper tubing *C* and *D* soldered into holes drilled near the top and bottom of the tin.

A hole, *E*, is drilled in the bottom of the tin, and the lower end of the spiral is soldered into this hole. A hole is drilled in the lid of the tin, and the lid is then soldered to the tin and to the copper tube. The end *F* of the copper tube is soldered to a hole in the lid of the treacle tin. The impure water is heated in *A*, and the water vapour is condensed in the copper spiral by sending in cold water at *D*.

Salt solution may also be slowly evaporated in a saucer. When all the water has disappeared the salt will be left behind on the saucer.

The Formation of Clouds, Dew, and Hoar-frost

The apparatus illustrated in connexion with cooling produced by evaporation may also be used to demonstrate the formation of clouds, dew, and hoar-frost. The intense local cooling produced near the apparatus causes the air to become saturated with moisture, forming a small cloud of mist. To demonstrate the formation of dew and hoar-frost the aluminium cup from a vacuum flask should be used instead of the cylindrical tin. As the ether evaporates the formation of dew can be seen on the outside of the aluminium cup, and after further evaporation the dew changes to hoar-frost.

The formation of mist can be illustrated by causing saturated air to expand and thus become cooled. A large round-bottomed, perfectly clean flask with a layer of water about a centimetre deep, and a rubber bung with two holes, should be allowed to stand for a short time until the air in the flask has become saturated. Through one of the holes in the bung is fitted a thermometer, and through the other hole a piece of glass tubing connected by means of a rubber tube to the mouth or, better still, to an exhausting pump. On sucking air out of the flask a momentary formation of mist and a reduction of temperature will be noticed.

Fall of Temperature with Increase of Altitude

The fall of temperature with increase of altitude may be proved by taking the temperature near the earth and then sending up a small minimum thermometer, sheltered from the sun and attached to a balloon filled with coal-gas, connected to earth with a known length of cotton.

When taking the temperature near the earth the temperature of the air within a few feet of the ground should be taken, as the temperature of the ground itself may be distinctly different. The thermometer should not be placed near a wall, in the direct rays of the sun, or where it will receive undue radiation from the earth. A thermometer screen is really necessary, but where this is not available, the thermometer should be attached to a string and whirled round in the air.

Suitable pilot balloons of good-quality rubber, with necks, and capable of inflation without bursting to 70 in. circumference can be obtained from Messrs Baird and Tatlock, Ltd, 14-17 St Cross Street, Hatton Garden, London, E.C.1.

A method of filling these pilot balloons was described under Topic (A).

Further Details of Teaching Aids, Models, Sources of Information, etc.

Chapter VII of Philip Lake's *Physical Geography* (Cambridge University Press, 1929) contains some valuable information on water in the air, Dr A. Wells's and Dr B. Aitken's theories on the formation of dew, and Dr B. Aitken's and Mr C. T. R. Wilson's theories on the formation of mist, cloud, and rain.

The following films are valuable teaching aids where a suitable projector is available:

Clouds and Rain (16 mm., silent, 1 reel) (Central Film Library).

Water in the Air (16 mm., sound and silent, 1 reel) (G.B. Equipments, Ltd).

(Explains the transformation of invisible water vapour in the air into clouds, fog, and rain, both by means of simple laboratory experiments and photographic studies of the formation of various types of clouds, shown at normal and super-animated speeds.)

The Water Cycle (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Shows the continuous circulation of water from earth to sky and back to earth, with examples of evaporation, condensation, and precipitation.)

Fog (16 mm., sound, 3 reels) (Army Kinema Corporation).

Ice Formation (16 mm., sound, 3 reels) (Army Kinema Corporation).

For definitions and beautiful reproductions of photographs of cloud forms the Air Ministry Meteorological Office publication No. 233 (third edition), *Cloud Forms*, should be consulted. It is only necessary to deal with the four fundamental types as proposed by Luke Howard at the beginning of the nineteenth century—namely, cirrus, the thread cloud; cumulus, the heap cloud; stratus, the flat cloud, or level sheet; nimbus, the rain cloud.

Film-strips

Snow and Ice Crystals (Newton and Co., Ltd).

Hygrometers

The moisture content of the air is one of the chief factors which decides the kind of weather to be expected, wet or fine; and an instrument which will reveal something about the wetness of the air will provide a rough guide to the weather. Such instruments are not difficult to make, and senior pupils can usually suggest how hygroscopic substances can be used for this purpose.

Dr A. Curry's chemical hygrometer, which indicates the degree of moisture in the air by change of colour, and also enables the observer to forecast the weather by combining the two factors

atmospheric moisture and the direction of the wind, can be obtained from Messrs Baird and Tatlock, Ltd, 14-17 St Cross Street, Hatton Garden, London, E.C.1.

A bundle of seaweed may be used to make a simple hygrometer, which may be calibrated to give the percentage of humidity, by comparison with a paper hygrometer giving direct percentages of humidity. Such a paper hygrometer is very useful for detecting excessive dampness of beds, and can be obtained from Messrs A. Gallenkamp and Co., Ltd, 10 Clifton Street, Finsbury Square, London, E.C.2. Exercise 101, *Everyday Science Topics*, Book II, illustrates simple hygrometers.

A wet- and dry-bulb hygrometer can be constructed, using two similar thermometers supported in a screen at a distance apart of 3-4 in., and, by its aid, the hygrometric state of the air can be readily determined by reference to tables. The Meteorological Office publication No. 265 (third edition), *Hygrometric Tables for the Computation of Relative Humidity, Vapour Pressure, and Dew Point from Readings of Dry- and Wet-bulb Thermometers exposed in Stevenson Screens*, is recommended for this purpose. A piece of muslin should be loosely wrapped round the bulb of one of the thermometers and the lower part of the muslin should be folded round a piece of lamp wick which has been boiled with washing-soda to remove grease. The other end of the wick should dip into an unspillable ink-well, placed to one side of the thermometer and filled with water.

The Rainbow

With a round-bottomed flask and a beam of light from an optical lantern the beautiful phenomenon of the rainbow can be demonstrated in the science room. The flask represents the raindrop, and the beam of light from the lantern acts in the same way as the sun's rays. The observer stands with his back to the lantern, and the eye must be moved about until it catches the position of the bow. The arrangement of apparatus and observer is illustrated.

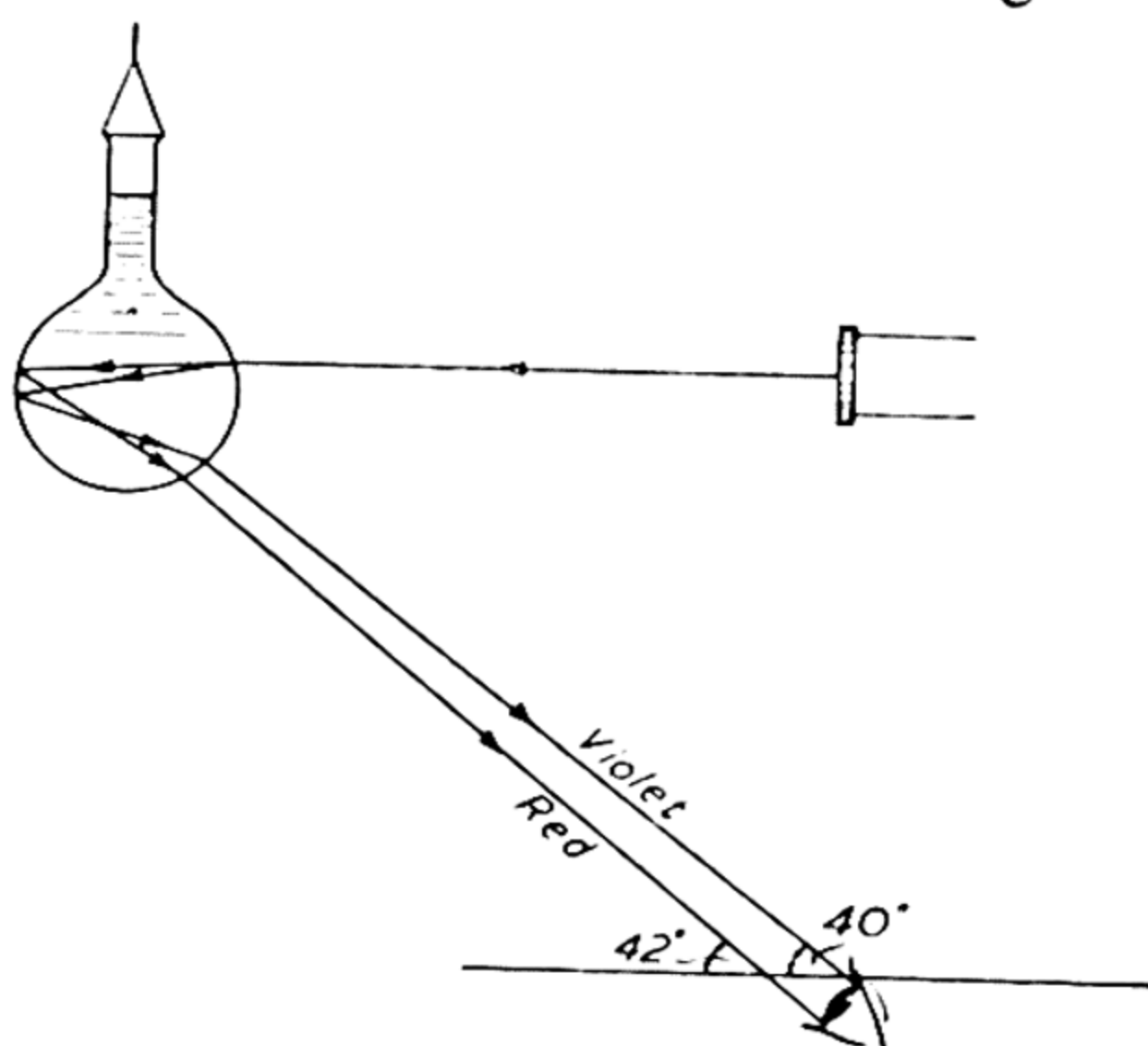


FIG. 105. A RAINBOW IN THE SCIENCE ROOM

For simple experiments on the composition of white light and the production of a spectrum, reference should be made to *The Teaching of 'Colour' in Elementary Courses of Science*, by Sir E. G. Savage. This little book also contains a description of a simple method of carrying out Tyndall's beautiful experiment which illustrates, at the same time, the redness of the sky at sunset and the blueness of the sky. In the words of the author, "the experiment is not done as often as it deserves to be."

Haloes round the moon often provoke children to ask questions about their formation. Although this is certainly outside the scope of elementary work, there is no reason why the phenomena should not be imitated in the laboratory. A method of doing this is also described in Sir Edward Savage's book. Beautiful haloes of light can be produced by spreading a saturated solution of alum over a plate of glass. A few drops will crystallize quickly, and the crystals are so small they cannot be seen. The glass is held between the sun or artificial light and the eye, with the smooth side of the glass to the eye.

Lightning

Senior pupils are always keen to learn something about lightning, and much useful and helpful information can be given without going into the theory of electrostatics. If lightning is to be imitated in the science room a Wimshurst machine is necessary. A number of my senior pupils thoroughly enjoyed making the machine described in Mr V. E. Johnson's *Electrical Recreations*. With this machine sparks of three to four or even five inches can be obtained. A local carpenter will usually turn up the bosses for a few pence, and the driving pulleys are best made from plywood discs with chamfered edges. Two discs are glued together with the chamfered edges together. Ready-made Wimshurst plates can be obtained from the Economic Electric Company, 64 London Road, Twickenham, and they also sell Leyden jars. Methods of making a Wimshurst machine are also described in *The Wimshurst Machine*, by A. W. Marshall, and *The Boy Electrician*, by A. P. Morgan and J. W. Sims.

When a Wimshurst machine is available the mechanical and heating effects of lightning can be imitated. A sheet of cardboard is readily perforated by the discharge from the machine, and sometimes a sheet of thin glass can be punctured by fixing a short glass tube to the plate by means of sealing-wax and using a thick copper wire as a terminal, which can be enclosed within the tube. The heating effect can be shown by connecting the two balls by a short

length of very fine wire. The wire is volatilized with explosive violence.

The action of a lightning-conductor can be demonstrated by fixing the apparatus illustrated in Fig. 106 to a discharging ball of a Wimshurst machine. *A* is a piece of $\frac{1}{8}$ -in. diameter brass rod passing through *B*, a length of ebonite rod, to one end of which is attached a candle in a wooden candle-holder. *A* is fixed to the discharging ball with sealing-wax, care being taken that the rod is actually in contact with the ball.

In certain atmospheric conditions clouds become charged to a high potential, and a disruptive discharge may take place either between oppositely charged clouds or between a cloud and the earth. By fixing an earth-connected point above the highest part of a building the charge on the cloud may be neutralized by the current of charged air which streams from the point.

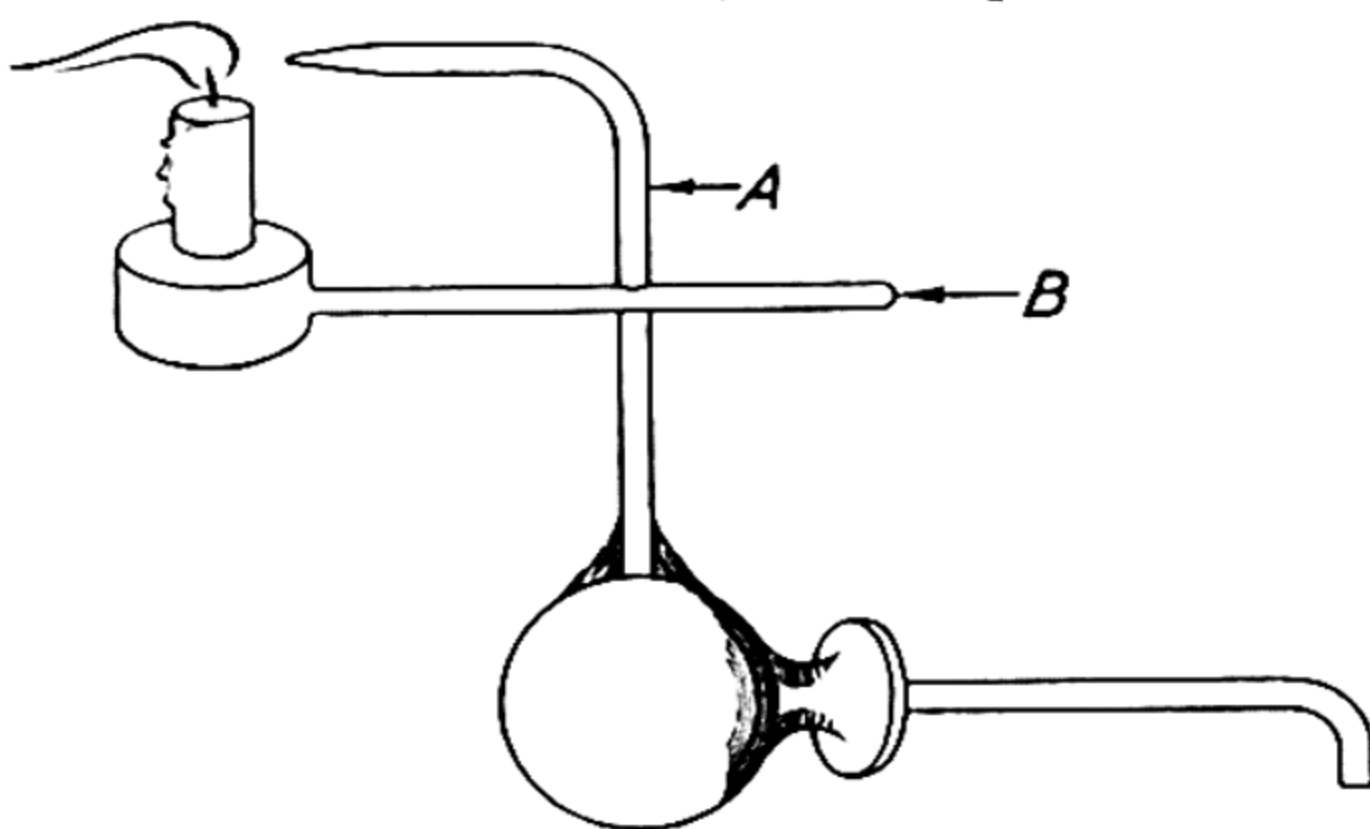


FIG. 106. ACTION OF A LIGHTNING-CONDUCTOR

A discussion of lightning invariably raises the question, "How do the clouds become electrified?" Electrification associated with evaporation has been mentioned among the possible sources, and this can be demonstrated in the science room. An electroscope for detecting the presence of static electricity is necessary, and can be made quite easily. The electroscope described at p. 184 of *The Science Master's Book*, Part I (Physics), Series I, is most satisfactory for this purpose.

With an electroscope available, the experiment referred to above can be carried out after the action of the electroscope has been shown. The experiment is described in detail at p. 192 of the above-mentioned book. A metal plate represents a cloud, and it can be shown how evaporation and condensation are both accompanied by electrical charges.

Further Information

Here are some useful reference books:

BULL, P. G.: *Simple Experiments in Static Electricity*.

PICKWELL, G.: *Weather*.

A New Relation between Atmospheric Electricity and Terrestrial Magnetism (Meteorological Office, 273r).

Lightning and Aircraft (M.O., 336f).

Observations of the Blueness of the Sky (M.O., 336j).

The Fog in London on January 31, 1918 (M.O., 232c).

The Formation of Thunderstorms over the British Isles in Winter (M.O., 245i).

The Thunderstorm which caused the Disastrous Floods at Louth on May 29, 1920 (M.O., 240g).

Making a Thunder-shower

It is a matter of common experience that raindrops in thundery weather are larger than usual. Professor C. V. Boys, in his book

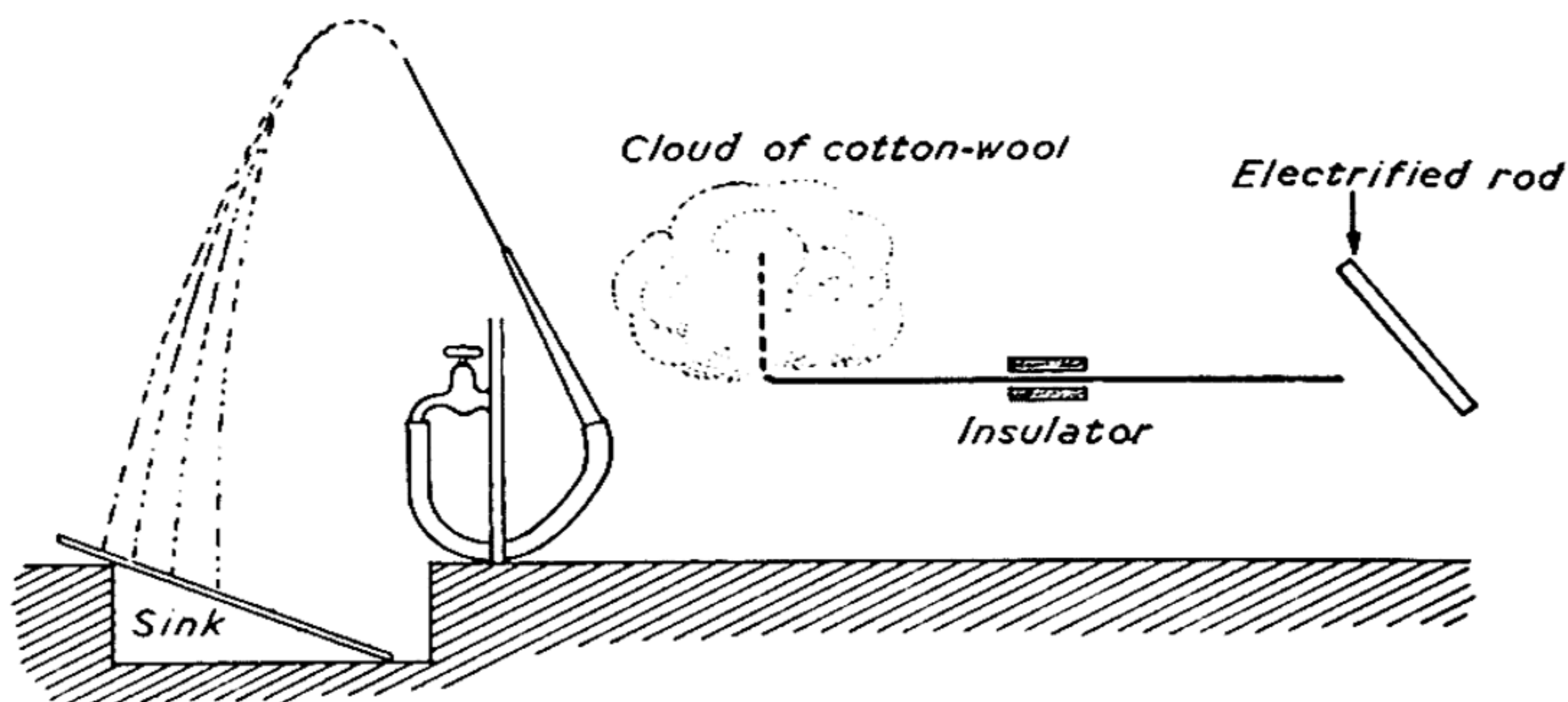


FIG. 107. THUNDER-SHOWER

Soap Bubbles, describes a simple method employed by Lord Rayleigh demonstrating this phenomenon.

The following is a modification making the method more picturesque for the benefit of the senior-school science pupil.

Connect a glass jet to a water-supply so as to produce a fountain about four feet high. The drops from this scatter to form a fine shower of 'rain.' This can be allowed to patter on to a sheet of brown paper, a wooden tray, or an inverted enamelled wash-bowl.

Next bend a length of stout wire—e.g., 16 gauge—at right angles, and set it up in a retort-stand clamp, using two pieces of rock sulphur, ebonite, or paraffin-wax to insulate it. Hang upon the vertical portion a large mass of cotton-wool. This is the 'storm-cloud.' Stand this part of the apparatus so that the 'cloud' is a foot or six inches from the jet.

Electrify a vulcanite fountain-pen by stroking it upward against the hair at the back of the head or by any of the standard methods. Place this in contact with the wire, thus electrifying the 'cloud.' The fine drops scattering from the fountain instantly coalesce to

form larger ones, falling with a heavy patter on the paper. Discharge the 'cloud' by touching the wire, and the gentle shower reappears. Do not electrify the jet too strongly or the drops are apt to scatter in an undesirable manner.

This demonstration requires the simplest of apparatus, and takes a very short time to prepare. It can readily be carried out by the children themselves. They like it and learn from it. Let them try.

How the Sun warms the Earth

The air is but little affected by the direct rays of the sun. It is warmed to some extent by radiant heat from the earth, and still more by contact with the earth, which absorbs the heat rays from the sun. It is warmed from below, and it is therefore reasonable that the temperature of the air should decrease upward.

A simple experimental illustration of this can easily be carried out. On a calm sunny day hang a thermometer in the open air in the direct rays of the sun. The mercury rises and the thermometer shows a high temperature. Now swing the thermometer round, still in the open air and still in the sun. The mercury falls at once, although it is just as much exposed to the sun's rays as before. The sun warms the thermometer, but not the air.

If observations of the temperature of the upper air are to be made with the aid of a balloon, as already described, the thermometer must be protected from the sun's rays.

The above experiments illustrate the need for a thermometer shelter for the maximum and minimum thermometer and the wet- and dry-bulb thermometers. Full instructions for making such a shelter are contained in the following books:

Instructions for making Thermometer Screens of the Stevenson Type (Meteorological Office, Form 63).

Meteorological Observer's Handbook.

SPEAKMAN, C.: *Handwork Science.*

The need for thermometers and the unreliability of our temperature sense is very well demonstrated by arranging three bowls, *A*, *B*, and *C*, so that *A* contains cold water, *B* tepid water, and *C* hot water. Ask a pupil to immerse his right hand in *C* and his left hand in *A*. Now ask the pupil to plunge both hands into *B*, and the water in this bowl will feel cold to the right hand and warm to the left hand.

Messrs Negretti and Zambra, who have made thermometers for more than eighty years, will be pleased to supply full particulars and to lend slides representing the various processes in the making of thermometers.

The following film is excellent for use in connexion with this section of work: *How the Sun's Rays heat the Earth* (16 mm., silent, 1 reel) (Educational and General Services, Ltd, Tower House, Woodchester, near Stroud, Gloucestershire).

An excellent chapter on "A Thermometer" is contained in *The New Practical Physics*, Book III, by F. Anniss. This chapter also contains a diagram of interesting temperatures and helpful suggestions for practical work.

Film-strips

Expansion of Metals (British Industrial Films, Ltd).

Thermometers (Common Ground, Ltd).

Electrical Discharges (Newton and Co., Ltd).

Thermometers

Everyday Science, Book II, by H. E. Bean, contains a useful chapter, "How Temperature is Measured." This includes instructions for making a simple air thermometer, a water thermometer, and a compound bar. Fig. 108 illustrates how a compound bar may be used to make model metallic thermometers.

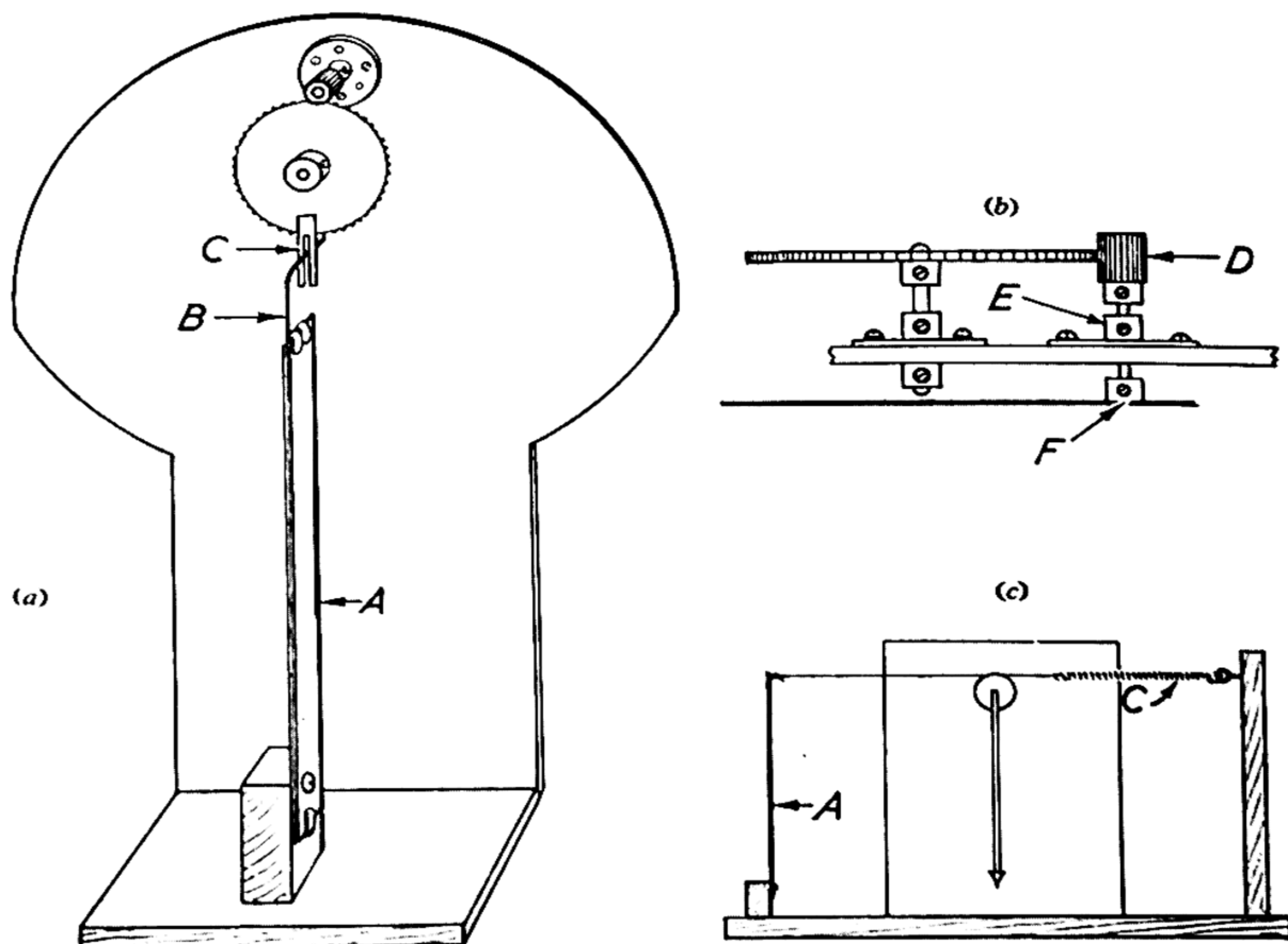


FIG. 108. COMPOUND BAR IN MODEL METALLIC THERMOMETERS

In Fig. 108 (a) *A* is the compound bar, made from a strip of brass and a strip of tin-plate, each $\frac{1}{2}$ in. wide and 12 in. long. *B* is a piece of wire soldered to the end of the bar, and *C* is a tin-plate fork soldered to the rim of a Meccano gear wheel, which engages with a Meccano pinion wheel. These Meccano parts can usually be obtained from boys without difficulty.

The method of mounting the wheels is indicated in Fig. 108 (b). *D* is the pinion wheel fixed to a short length of rod, *E* is a Meccano bush-wheel which is screwed to the plywood, and in which the rod revolves, and *F* is a collar fixed to the rod and holding the pointer.

In Fig. 108 (c) *A* is the compound strip, to the upper end of which is attached a piece of thin string, which passes once round a Meccano pulley-wheel fixed to the plywood, as illustrated in Fig. 108 (b), and is then fastened to a spring *C*.

A School Meteorological Station

Valuable meteorological observations can often be made with improvised apparatus such as that already described, and the building up of a school meteorological station provides excellent opportunities for co-operation between the various departments in a secondary school.

Many such schools are ideally situated for making such observations, which should include rainfall, direction and velocity of the wind, temperature, air pressure, altitude of the sun at different times of the year, number of rainy days, proportion of days on which wind blows from any one quarter, and hours of sunshine.

The following apparatus is required: a wind-vane, a rain-gauge, an anemometer, a sunshine recorder, a sun's-altitude finder, maximum and minimum thermometers, hygrometer, barometer, thermometer shelter, and charts for records of observations.

Methods of improvising much of this apparatus have already been described. Second-hand apparatus can often be obtained locally or from: City Sale and Exchange, Ltd, 66 Cheapside, London, E.C.2; C. Baker, 244 High Holborn, London, W.C.1; Electradix, 214 Queenstown Road, London, S.W.8.

Messrs Baird and Tatlock, Ltd, 14-17 St Cross Street, Hatton Garden, London, E.C.1, will supply a revised edition of their list of meteorological apparatus to teachers free of charge. This is a beautifully illustrated list, and is of great value for use with the episcopes.

The meteorological apparatus contained in Messrs A. Gallenkamp's portable meteorological outfit is quite suitable for secondary schools.

Wind-vane and Anemometer

A combined wind-vane and anemometer is illustrated in Fig. 109. The wooden upright *A* is about 8 ft. high, and the tin-plate funnels *B* are 6 in. in diameter at the open ends and 10 in. in height. The two pieces of wood *C, C* are joined by a half-lap joint, and the method of supporting this on the top of the pole is indicated in the

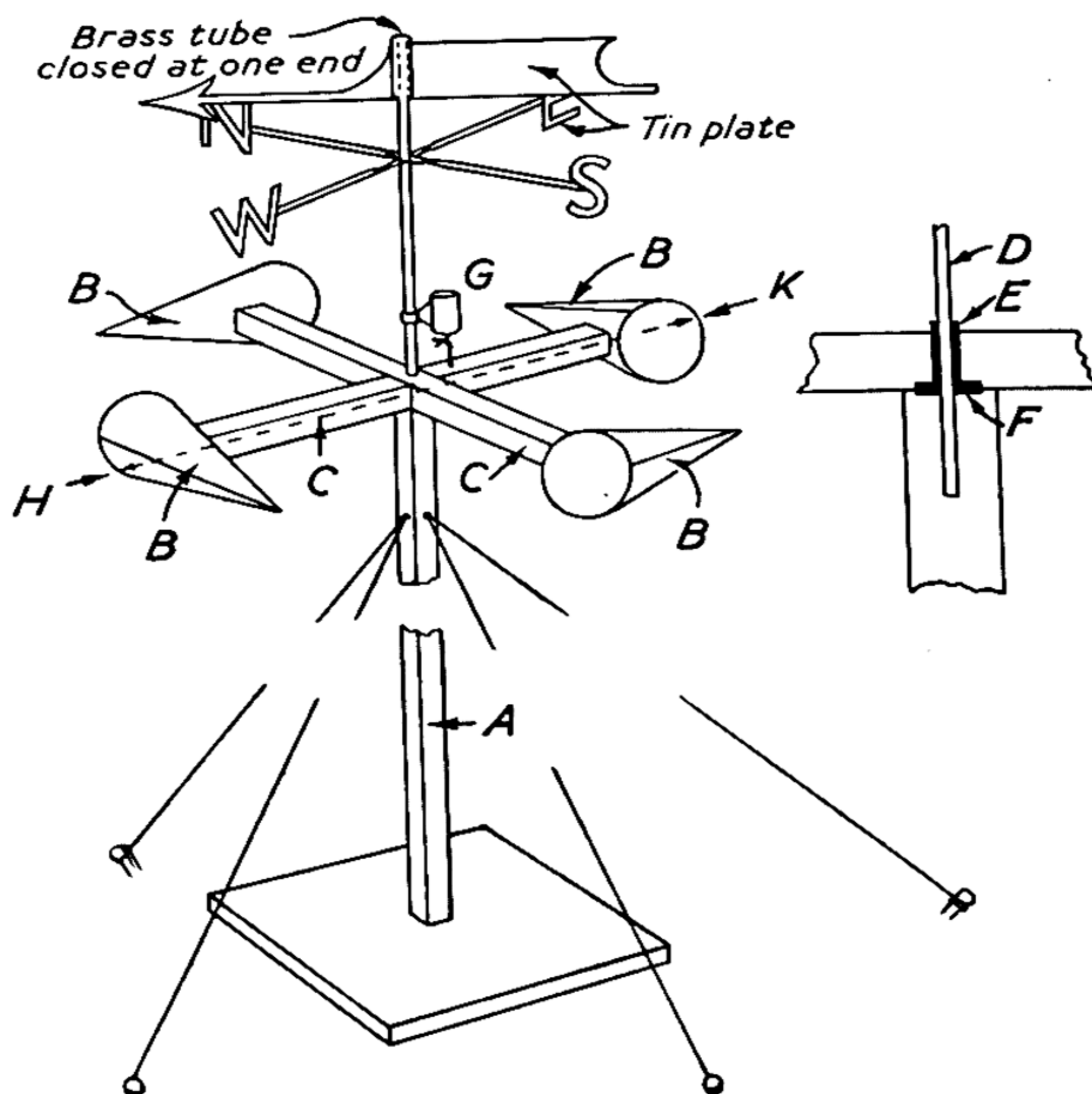


FIG. 109. WIND-VANE AND ANEMOMETER

smaller diagram. *D* is a steel rod sunk into the upper end of the pole to a depth of about 6 in. *E* is a piece of brass tube, and *F* is a ball-race which fits into slots made in the upper end of the pole and where the pieces *C, C* are joined. *G* is a cyclometer for a 28-in. cycle wheel, and the distance *HK* is 28 in.

A reading of the cyclometer is taken every twenty-four hours, and a rough measurement of the speed of the wind in miles per hour can be made. A more reliable calibration of the instrument can be made by comparison with an accurate anemometer, if such is available.

A Sunshine Recorder

A model sunshine recorder which will give some results is illustrated below. The woodwork and metalwork departments rendered valuable assistance in making the apparatus illustrated.

A is a round-bottomed flask filled with water which has been freed from air by boiling, and *B* is a piece of brass beaten out so as to form part of a spherical surface, with all parts at a distance away from the surface of the flask equal to the focal length of the glass-and-water sphere, which is determined by holding the sphere in the sun above a piece of paper. Thin card with an unglazed blue surface is cut into strips, moistened, pressed up against the metal surface, and held there with paper-clips. The card takes on the shape of the metal when dry, and is calibrated by comparison with a watch at various times of the day.

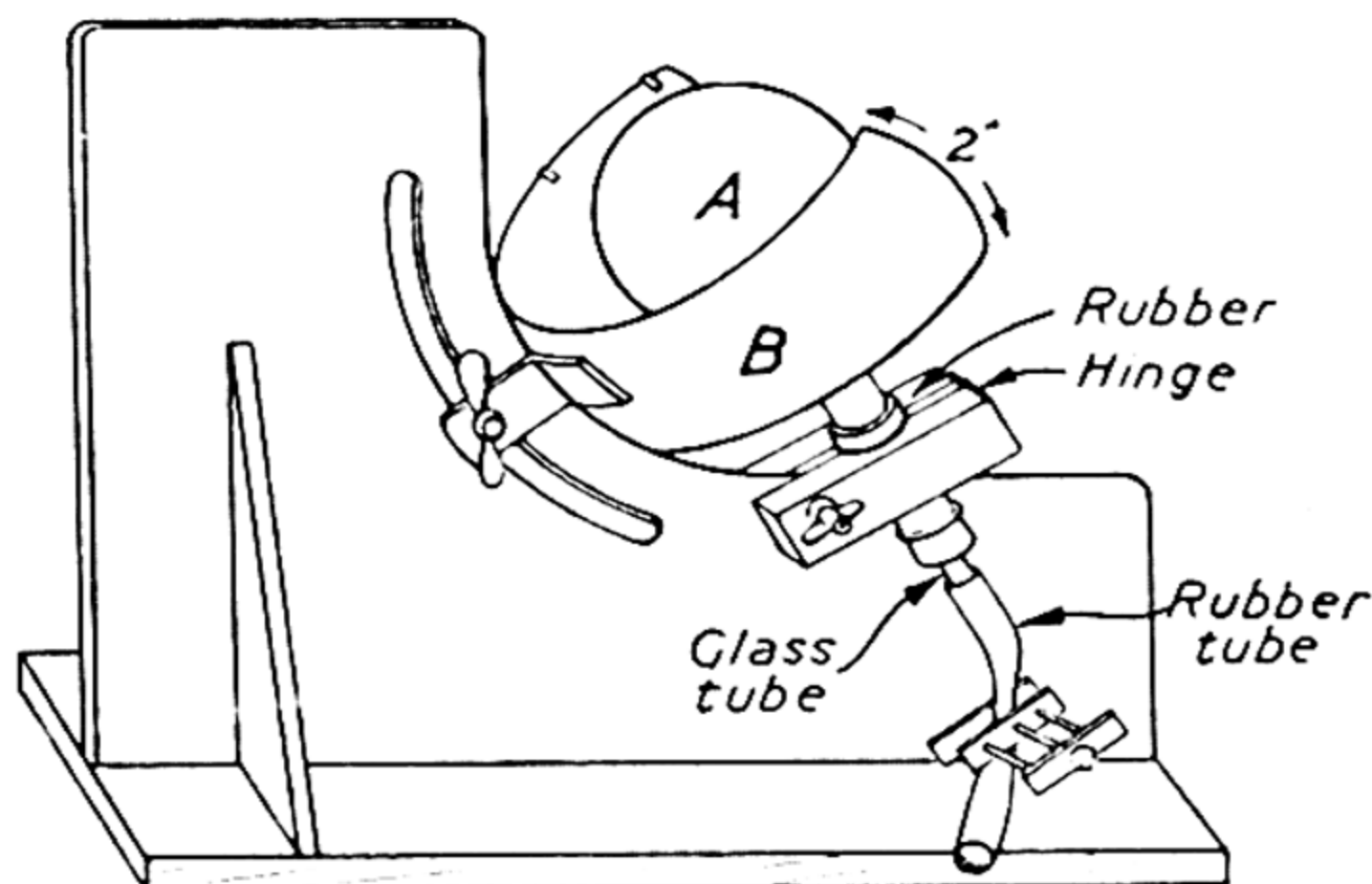


FIG. 110. SUNSHINE RECORDER

Further Information

For recording meteorological observations the following publications are recommended:

Climatological Diagram to show Daily Values of Sunshine, Winds, Pressure, Temperature, Rainfall, and Weather for One Week (Meteorological Office, Form 3096).

Meteorological Diagram Register for One Year (M.O., Form 1121).

Meteorological Register for One Year (M.O., Form 1123).

Other useful publications are:

Averages of Bright Sunshine for the British Isles for Periods ending 1935 (M.O., 408).

Averages of Temperature for the British Isles for Periods ending 1935 (M.O., 407).

The Comparison of Sunshine Recorders of the Campbell-Stokes Type (M.O., 273e).

All the above are obtainable from H.M. Stationery Office, York House, Kingsway, London, W.C.2.

Science and the Weather, No. 16, in the "Model Engineer" series, published by Percival Marshall and Co.

Meteorological Instruments and Weather Forecasts is a really helpful handbook, describing the various instruments used for studying and recording the weather. Chapter VI, on weather forecasts and warnings, is excellent.

I should like to emphasize the value of the *Meteorological Observer's Handbook*, which contains, among other things, a set of meteorological tables, instructions and working drawings for making a thermometer screen, particulars of photographs and lantern-slides of meteorological instruments and phenomena, particulars of a syllabus of rudimentary instruction on a weather study for use in secondary schools, full descriptions of all instruments, photographs of cloud forms, and particulars of optical atmospheric phenomena.

Films

Helpful films that should be seen in this connexion are:

The Story of a Disturbance (16 mm., sound and silent, 1 reel) (G.B. Film Library).

Weather Forecast (16 mm., sound, 2 reels) (Central Film Library).

Weather Forecasting (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

(Shows collection, tabulation, and interpretation of weather data obtained from observation and instruments.)

Film-strips

Atmospheric Phenomena (Newton and Co., Ltd).

Study of Cloud Forms (Newton and Co., Ltd).

Weather and Weather Recording (Newton and Co., Ltd).

(R) Mirrors

Mention of the word 'mirror' usually brings to the minds of pupils in secondary schools the looking-glass at home. Few of them realize how many different types of mirrors there are, and the numerous applications of these in everyday appliances never fail to rouse their interest.

Work on this topic might well be introduced by displaying before the pupils plane mirrors of various kinds, cylindrical and spherical mirrors, and allowing them to examine the various images formed.

Large mirrors can be obtained from cheap stores, and these can be cut up into small rectangular pieces. Small pieces of brass plate, well polished with metal polish, or pieces of tin plate or aluminium sheet make quite good plane mirrors. Cylindrical mirrors can be made from well-polished brass plate, sheet aluminium, or tin plate. Cylindrical convex and spherical convex mirrors can be improvised by pouring mercury or black ink into a beaker and a flask respectively.

Making Mirrors

A method of making a cylindrical concave and cylindrical convex mirror is illustrated in Fig. 111.

One glass dish is placed inside another and held there with a weight. Suitable dishes can often be obtained from cheap stores. Silvering solution, consisting of equal parts of silver nitrate and ferrous sulphate solutions, is placed in the space between the two dishes.

Hot water is poured into the inner dish, and this may be kept hot by passing in steam for a short time. This causes deposition of silver on the outside of the inner vessel and on the inside of the outer vessel. The silvering can be scraped off where it is not required on one half of each dish, while that left on the other half can be protected with a layer of paint, otherwise it will soon tarnish.

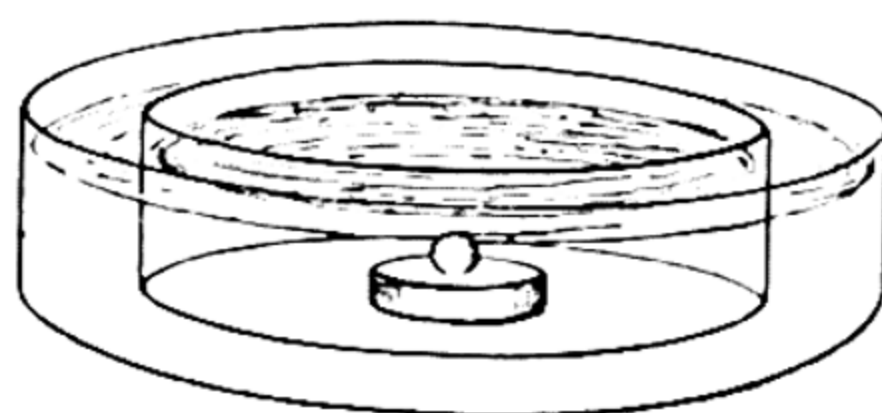


FIG. 111. MAKING
CYLINDRICAL MIRRORS

The experiment illustrates a method of making mirrors and the need for the paint on the back of looking-glasses, and always arouses great interest. Second-hand driving-mirrors and parabolic headlamp reflectors can usually be obtained from garages or places where old cars are broken up.

The Nature of Light

I most certainly think that we should attempt to give to senior pupils some idea of the true nature of light. Experiments with pins and narrow beams of light have been very misleading in the past. Pupils have learned to regard light as a material substance, and the beams in the smoke-laden atmospheres of the cinemas have probably been largely responsible for this.

When light-waves fall on minute particles in the air, or elsewhere, these become luminous and can be seen, but through perfectly clean air the path of a beam of light is not visible—a very important fact to impress on the minds of our pupils. This can be demonstrated by passing a beam of light from an optical lantern across a darkened room. If the air is free from dust, pupils will be able to see where the beam leaves the lantern and the patch where it strikes the opposite wall and thus makes it luminous. In between nothing will be seen. If the blackboard duster is now shaken in the path of the light, the particles will float about and reveal this path. If the path is revealed in this way near the lantern, a Bunsen burner flame may be brought below the beam so as to burn up or volatilize the

particles. The air becomes dust-free, and above the flame the path of the light cannot be seen.

Having now emphasized the fact that light is invisible, we might attempt to demonstrate the nature of its transmission. It is not a difficult matter to convince pupils that light passes through a space where there is nothing. Air is not the medium by which light is propagated, as it is for sound. An electric bell ringing in a good vacuum cannot be heard, but it can be seen.

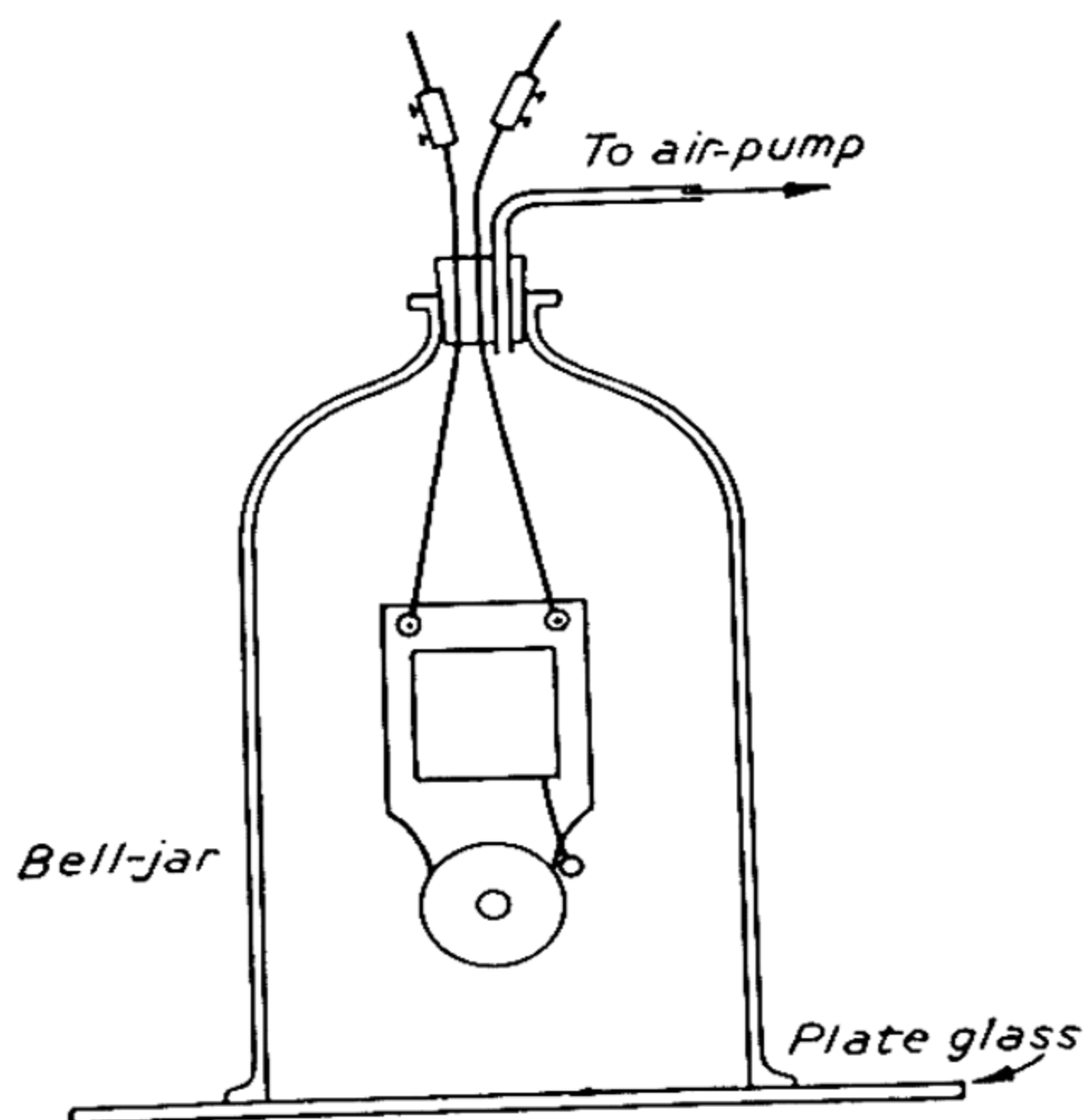


FIG. 112. ELECTRIC BELL IN A VACUUM

A method of demonstrating this is illustrated in Fig. 112. A bell-jar, the rim of which is coated with Vaseline, is placed on a piece of plate glass. The electric bell is suspended by means of copper wires which pass through a rubber bung. The space inside the bell-jar can be exhausted by using the air-pump described at p. 136.

The nature and behaviour of light-waves may be demonstrated by using the apparatus illustrated in Fig. 113.

When this has been done, narrow parallel beams of light on vertical or horizontal surfaces may be used to show the reflection of light by mirrors, emphasizing always that these narrow beams really indicate the path of a wave motion.

This wave-motion apparatus is really a form of ripple tank, which can be made at a small fraction of the cost of a manufactured tank.

The wooden frame *A* is fitted with glass sealed

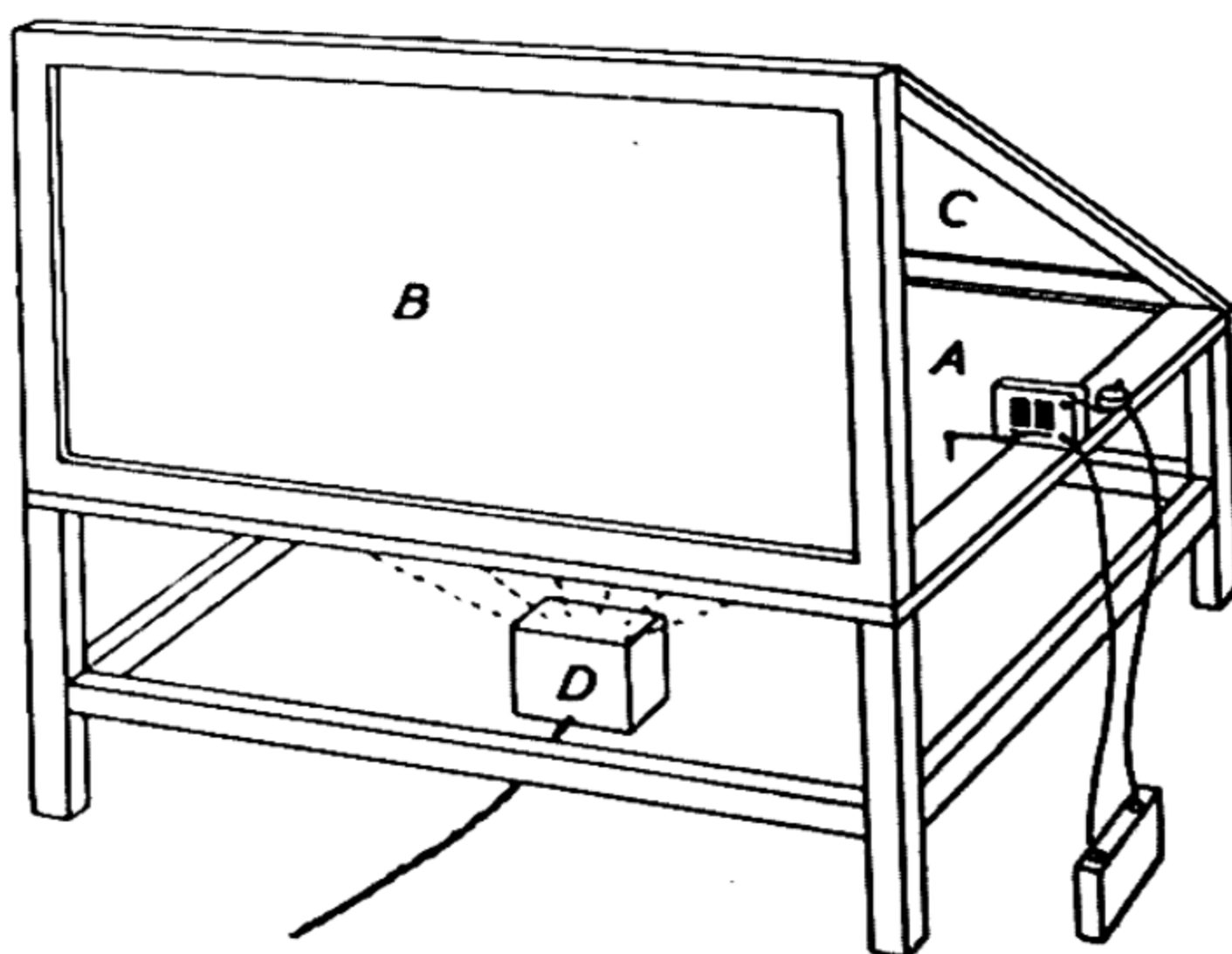


FIG. 113. APPARATUS FOR DEMONSTRATING LIGHT WAVES

in position with putty to make a shallow watertight trough about 3 ft. long and 2 ft. wide. The frame *B* is fitted with ground glass or Celastoid to act as a screen. Celastoid is excellent material for making translucent screens, and is obtainable from Newton and Co., Ltd, 72 Wigmore Street, W.1.

The frames *A* and *B* are fitted together at right angles by means of two iron shelf brackets, and the frame *C*, which carries a mirror, is screwed to the edges of *A* and *B*. The frames are supported on four upright legs held together by a frame, as in the diagram. *D* is a rectangular tin box with an electric lamp fixed inside, so that the light spreading from the rectangular opening of the box just illuminates the whole of the frame *A*. Water is placed in *A* to a depth of about $\frac{1}{4}$ in. Ripples are produced on the surface of the water by means of an electric-bell movement. A short piece of wire soldered to the knob of the bell movement just touches the water. Ripples are produced by pressing the bell-push.

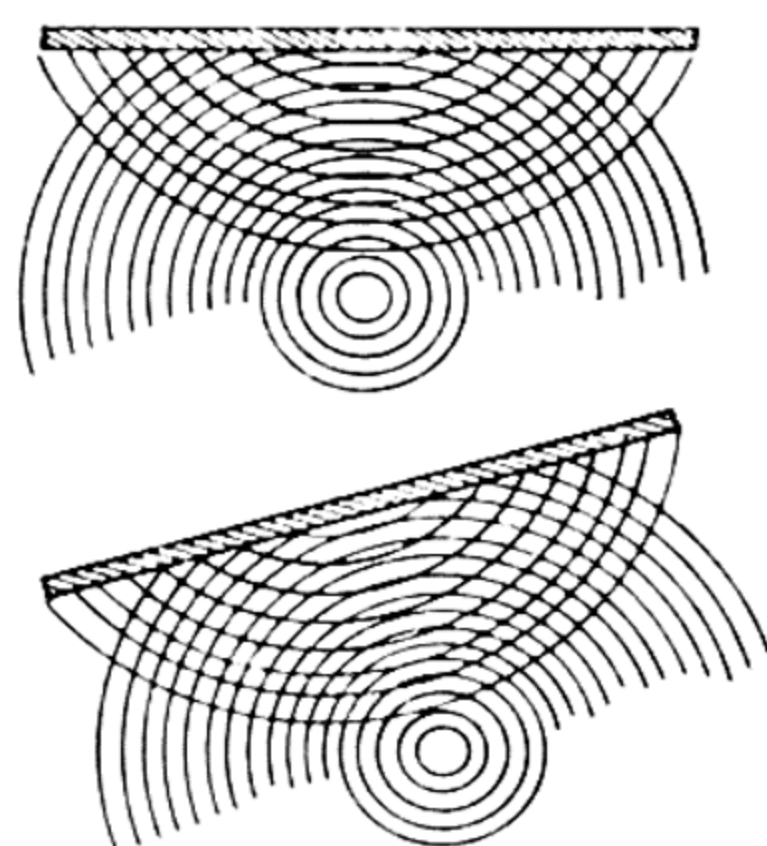


FIG. 114. MOVEMENT OF WAVES IN A RIPPLE TANK

The action of mirrors on light-waves can be demonstrated by placing in the water a piece of wood with its surface previously moistened. Fig. 114 illustrates what is seen on the screen with the wood in two different positions. The action of curved reflectors can be demonstrated by using curved wooden surfaces.

Demonstrating the Action of Mirrors

After the preliminary discussions and demonstration on types of mirrors and the transmission and nature of light, narrow parallel beams of light on horizontal or vertical surfaces may be used to demonstrate reflection of light. When demonstrations are to be given to small groups or for individual work a sheet of white paper or cardboard may be laid on a table and the apparatus illustrated in Exercise 102, *Everyday Science Topics*, Book II, may be used.

Suitable convex lenses can be obtained from Philip Harris and Co., Ltd, 144 Edmund Street, Birmingham, 3. Cylindrical lenses can be made from that remarkable new material Perspex. There are numerous important uses for this new material in the Secondary School science room. It is more transparent and lighter than glass, and it is very tough. It can be sawn, filed, or tooled, and when heated in a hot-air oven it may be bent, twisted, or moulded to any

required shape. On cooling it regains its rigidity and does not lose its transparency.

A suitable hot-air oven for heating Perspex, sterilizing glassware for work with bacteria, etc., is shown in Fig. 115. It consists of a large biscuit-tin, supported on four pieces of strip iron, each about 9 in. long and riveted to one side of the tin. The rim of the lid along one side is cut away, and two brass hinges are soldered or riveted to the lid and side of the tin. The end of a clothes-peg fastened with a screw to the lid acts as a knob. Two pieces of tin plate or sheet brass with several holes, drilled as illustrated, act as shelves, and are supported on Meccano angle-girders fastened to the sides. Where riveting is not possible an excellent method of fastening one piece of metal to another is to drill holes of a suitable size with an ordinary hand-drill and then use Meccano nuts and bolts.

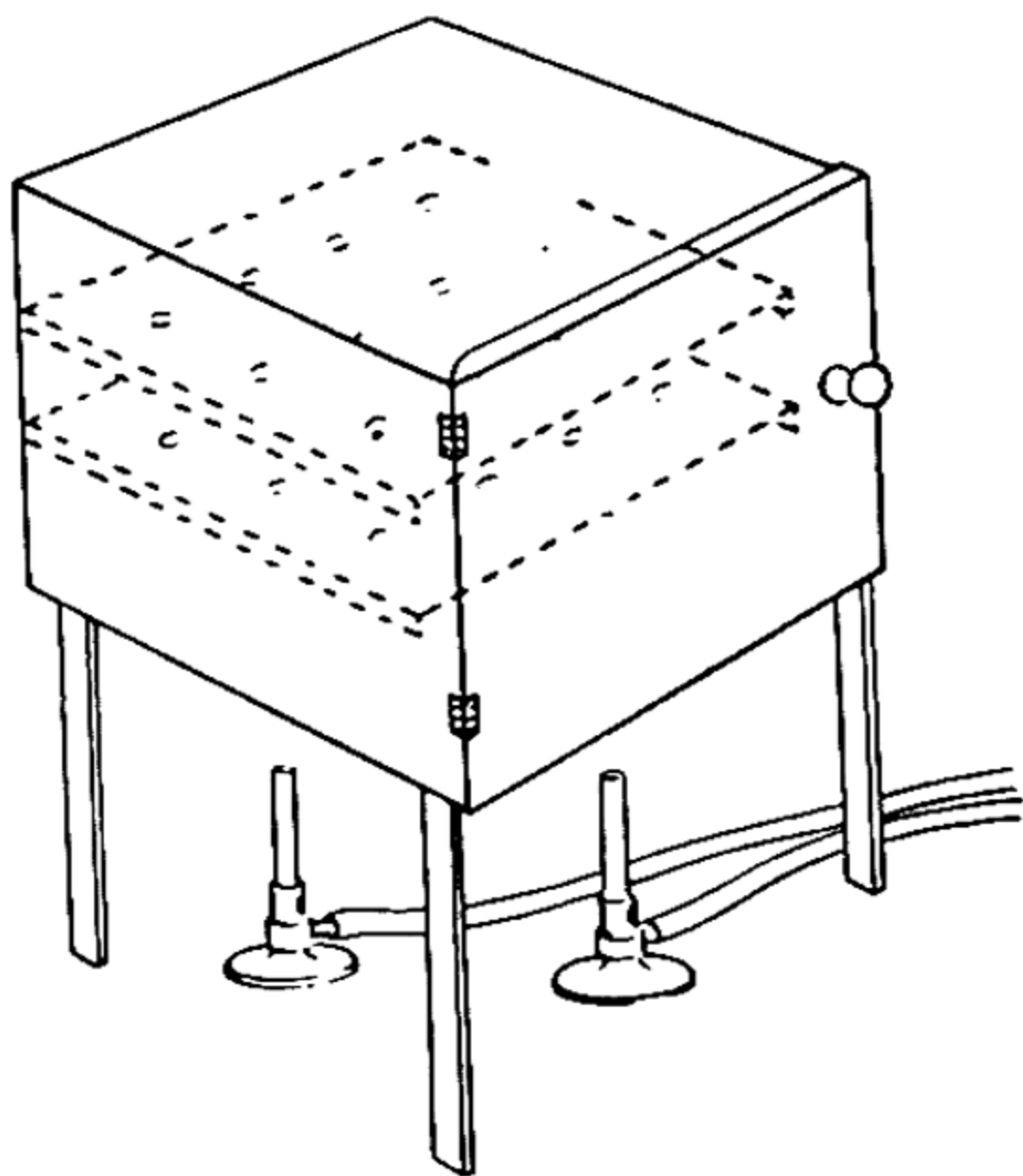


FIG. 115. HOT-AIR OVEN

lens (about 70 cm. double convex), due to F. A. Meier, is described at p. 61 of *The Science Master's Book*, Part 1 (Physics).

Other methods of demonstrating the action of mirrors on narrow beams of light, in horizontal and vertical planes, are described at p. 208 of *The Laboratory Workshop*, by Duckworth and Harries, at p. 62 of *The Science Master's Book*, Part 1 (Physics), and at p. 102 of *The Science Master's Book* (Series II), Part 1 (Physics). All the above books are included as essential teachers' reference books in the science library list given in Chapter VII.

Demonstrations of the action of mirrors, etc., on narrow beams of light are most effective, with a large number of pupils, when carried out on a vertical surface.

For those teachers who can afford them the following sets of optical demonstration apparatus are available:

(1) The "Nivoc" Optical Demonstration Apparatus. (Uses a vertical white metal screen.)

(2) The "Nivoc" Ray Track Apparatus. (Uses a white-painted horizontal board.) With each of the above a small booklet entitled

Experimental Optics for Schools is supplied. The above apparatus is obtainable from W. and J. George, Ltd, 157 Great Charles Street, Birmingham, 3.

(3) The "Lambeam" Optical Box.

(4) The "Meier" Optical Set. Items 3 and 4 are obtainable from Philip Harris and Co., Ltd, 144 Edmund Street, Birmingham, 3.

Position of the Image in a Plane Mirror

Pupils may find the position of the image in a mirror by using a piece of glass and two short pieces of candle of equal lengths. The

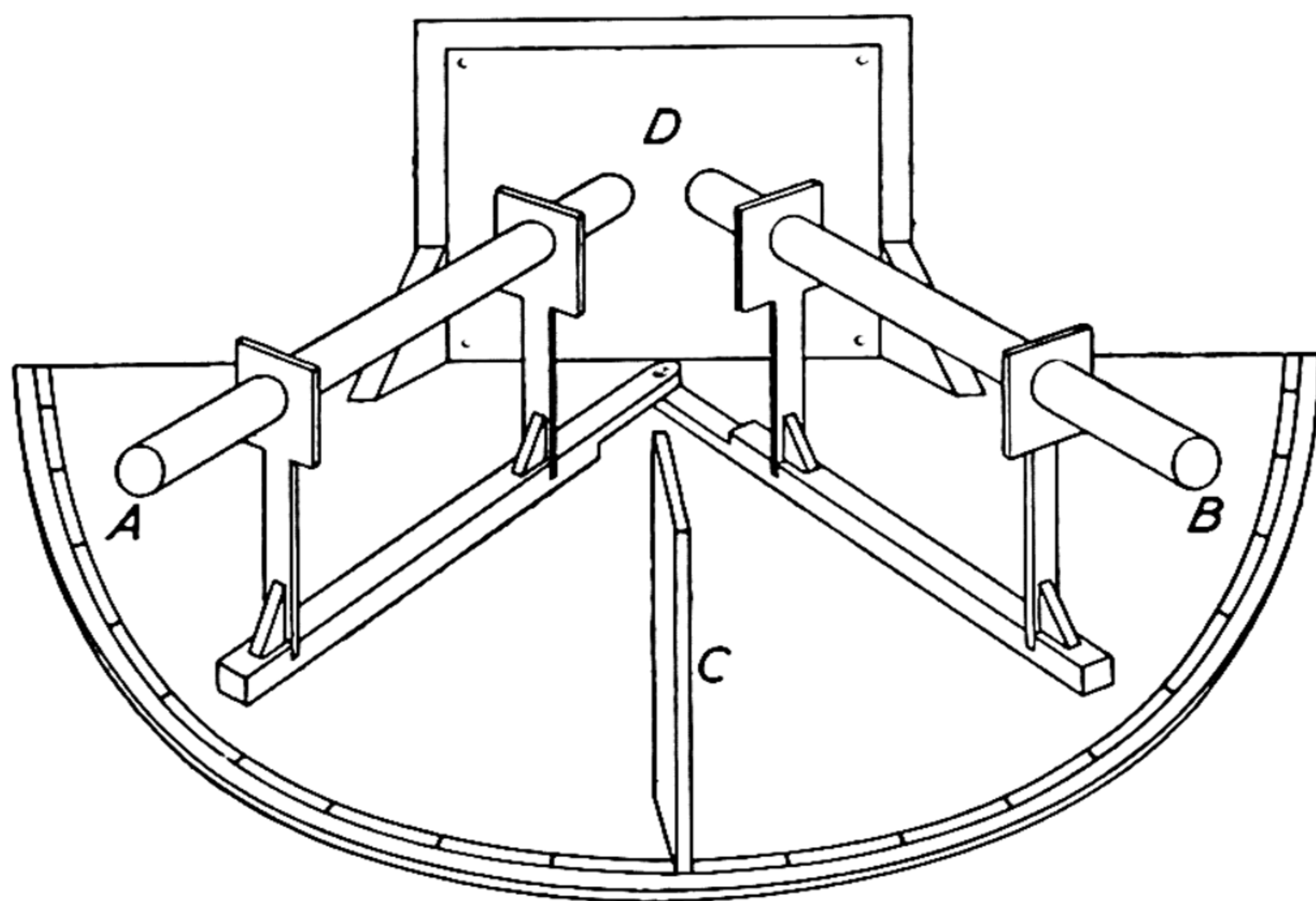


FIG. 116. APPARATUS FOR DEMONSTRATING REFLECTION

candles are lighted, one piece is placed in front of the glass, and on looking through the glass an image of this lighted candle can be seen behind the glass. The other piece of candle is placed behind the glass so as to coincide with the position of this image, whatever position the image is viewed from. The distances of the two pieces of candle can then be measured from the front and back of the glass. These distances will be found to be equal. A glass of water may be placed in the position of the image. A candle will then appear to be burning inside a glass of water when viewed from the front of the glass.

An excellent piece of apparatus which may be used to show the reflection of light and radiant heat and also sound-waves is shown in Fig. 116. Incidentally, the same piece of apparatus can be used

to demonstrate that the laws of reflection apply to radiant heat in the same way as they do to light.

A and *B* are cardboard or, better still, tin-plate tubes 2–3 in. in diameter, supported by pieces of plywood fixed to the horizontal wooden radial arms which move over the plywood base. Pieces of wire are fixed in the ends of the radial arms, and the base is marked out in tens of degrees. *C* is a wooden screen to prevent radiant heat or sound from passing straight across from the end *A* to the end *B*. *D* is a piece of sheet brass fixed to a piece of wood. The surface of the brass can be polished with metal polish when required. A piece of gas-fire radiant held in a Bunsen flame near the end of the tube *A*, or an electric heating element from a bowl-fire, serves as an excellent source of light and radiant heat. The radiant heat may be detected at *B* by means of a home-made thermoscope, a thermopile, or the blackened bulb of a thermometer.

The Periscope

I have found very helpful, for teaching purposes, a model periscope in which the whole of one side can be removed, by taking out the screws, to show the arrangement of the mirrors, as illustrated in Exercise 105, *Everyday Science Topics*, Book II.

The action of the mirrors in a periscope can be shown by using the apparatus illustrated in Exercise 102 of the same book for producing a narrow beam of light. Two mirrors are arranged on a sheet of white paper, as illustrated in Fig. 1, Exercise 105.

A simple form of periscope can be made by fitting two pieces of mirror into slits made in a piece of wood about 18 in. by 1 in. by $\frac{1}{2}$ in., as illustrated in Fig. 2, Exercise 105.

Increasing Illumination by using Mirrors

To increase the illumination in dark basement rooms in narrow city streets where the buildings are very tall, mirrors are sometimes placed outside the windows to catch the light from the sky above and reflect it into the rooms.

The model illustrated in Fig. 117 was designed to show this. The wooden box *A* represents the basement room. The inside of this is painted with cream distemper. The hole *B* represents the window, and *C* is a piece of ground glass which fits over another hole in the side of the box for observation purposes. *D* represents the narrow street between high buildings. The whole of this is painted with dead-black paint (made by mixing a little lamp-black with a solution of shellac in methylated spirit) to represent the dark, dirty exterior of

buildings in some narrow city streets. *E* is a 12-volt lamp attached to a lid hinged to *D*.

When the lid is closed and the lamp lighted, light passes down to the window, *B*. The mirror, *F*, should be taken away. By looking through *C* a measure of the general intensity of illumination in *A* can be obtained. The mirror should then be placed in position, with its bottom edge in a groove in the window and its upper edge held by a piece of narrow tape, as illustrated.

The position of the mirror can be adjusted until the intensity of illumination in the room is a maximum. By varying its position it can be seen how the intensity of illumination varies.

Mirrors in Shop-windows

Mirrors are often placed in shop-windows to attract customers. They also make the window-space appear larger, and all the objects on show are seen by reflection in the mirrors. This can be demonstrated in the science room by placing a mirror in the bottom of a box, which is then laid on its side on the bench. A number of miniature electric lamps wired in parallel to a switch and a battery and fixed inside the upper side of the box serve to illuminate objects placed in the box. The inside of the box should be painted white or covered with white paper.

The model illustrated in Fig. 118 may be used to show the principle of an illusion, first used on the stage about 1860, and recently revived by several firms for advertising purposes. In the illustration one plywood side, which should be fixed with screws, has been removed to show the interior of the box. The whole of the inside of the box should be painted with dead-black paint.

A is a piece of glass fixed at an angle of 45° , *B* is an alarm-clock, and *C* is a similar clock, suspended with black cotton, face uppermost, so that the image by reflection in the glass is exactly superimposed on the clock *B*. The back of the clock *C* is removed to show the works. Three 6-volt lamps, numbered 1, are wired in parallel to two terminals of the two-way switch, *D*, full details of which are given in the enlarged figure. The three lamps numbered 2 are wired in parallel to the other two terminals of the two-way switch. It will

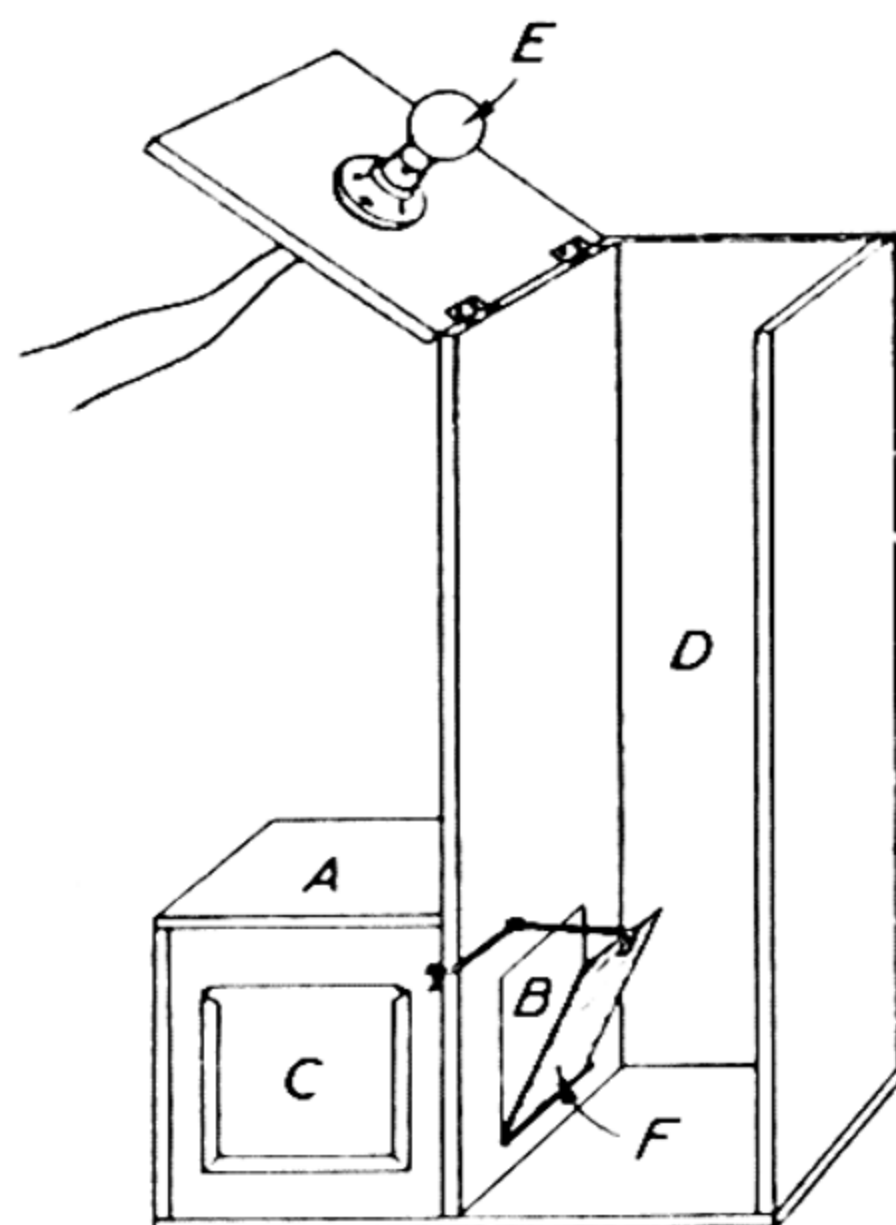


FIG. 117. MODEL TO SHOW THE USE OF MIRRORS ON BUILDINGS

be noticed that this two-way switch is constructed entirely from Meccano parts, with pieces of wood for handle and base. A plentiful supply of old Meccano parts can usually be obtained from the pupils.

To use the apparatus the lights numbered 2 are switched on, and the tin-plate reflector behind these concentrates the light on the clock *B*, which is seen on looking in the direction of the arrow. The

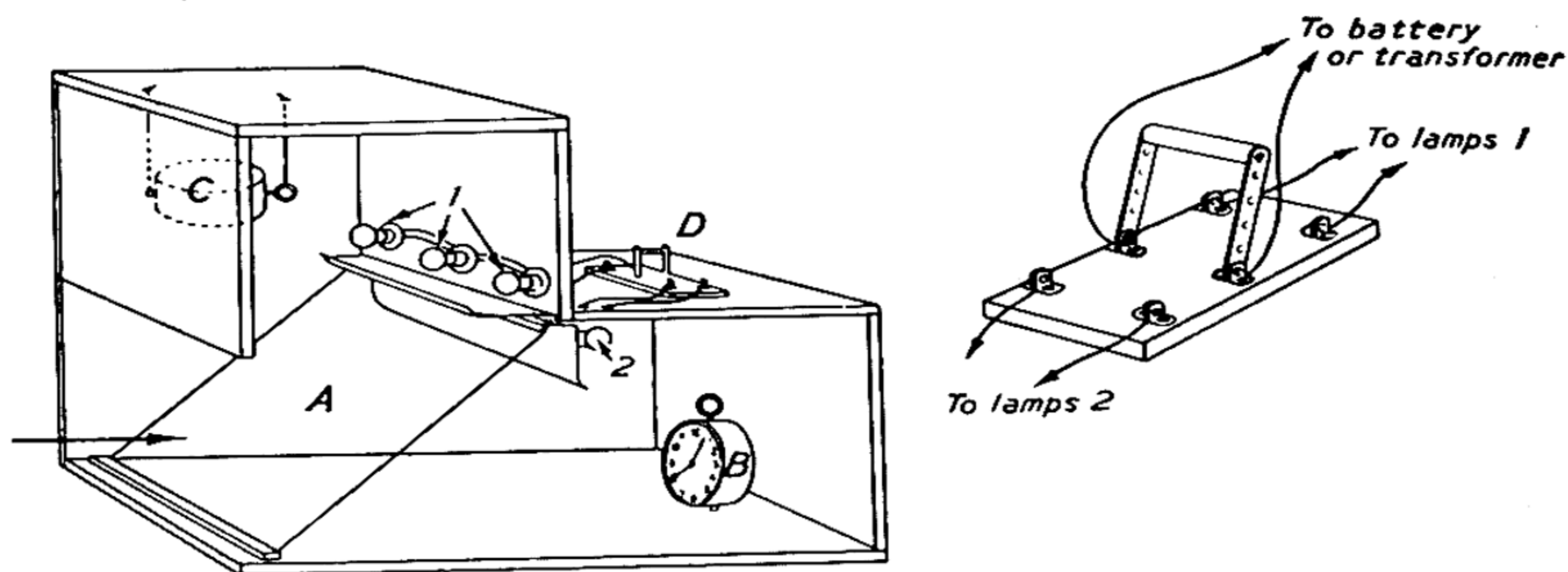


FIG. 118. APPARATUS FOR PRODUCING AN ILLUSION

lights numbered 2 are switched off, and those numbered 1 are switched on. An image of *C*, showing the works of the clock, will then be seen in the exact position of *B*.

The method of producing the illusion known as Pepper's Ghost can be demonstrated by using the apparatus on its side. A doll covered with a white cloth is placed in the compartment *C*, and lamps numbered 1 are switched on. A ghost-like image is produced in *B*.

A Pulsometer

The beating of the heart can be indicated by laying a very small, light piece of mirror over the pulse on the wrist, as indicated in the diagram, Fig. 119. A narrow parallel beam of light is allowed to fall on the piece of mirror, which reflects it on to a white screen, where a small circle of light is seen. The hand is kept quite still by laying it palm upward on the bench, and the reflected circle of light moves up and down on the screen. A method of constructing a simple spotlight projector for projecting a narrow parallel beam of light is also illustrated.

A is a piece of brass tubing about $1\frac{3}{8}$ in. internal diameter. To one end of this is soldered a brass ring, to which a short-focus convex lens is fixed on the inside with a brass-wire ring or Plasticine. The brass ring cuts off the light passing through the outer edges of

the lens. The whole of the inside of the tube should be painted dead black. *B* is a cylindrical piece of wood which fits inside the tube. This has a miniature lamp-holder fixed at one end, and, at the other end, a short piece of dowel rod is glued into a hole bored in *B*. The insulated wires from the lamp-holder pass through small holes

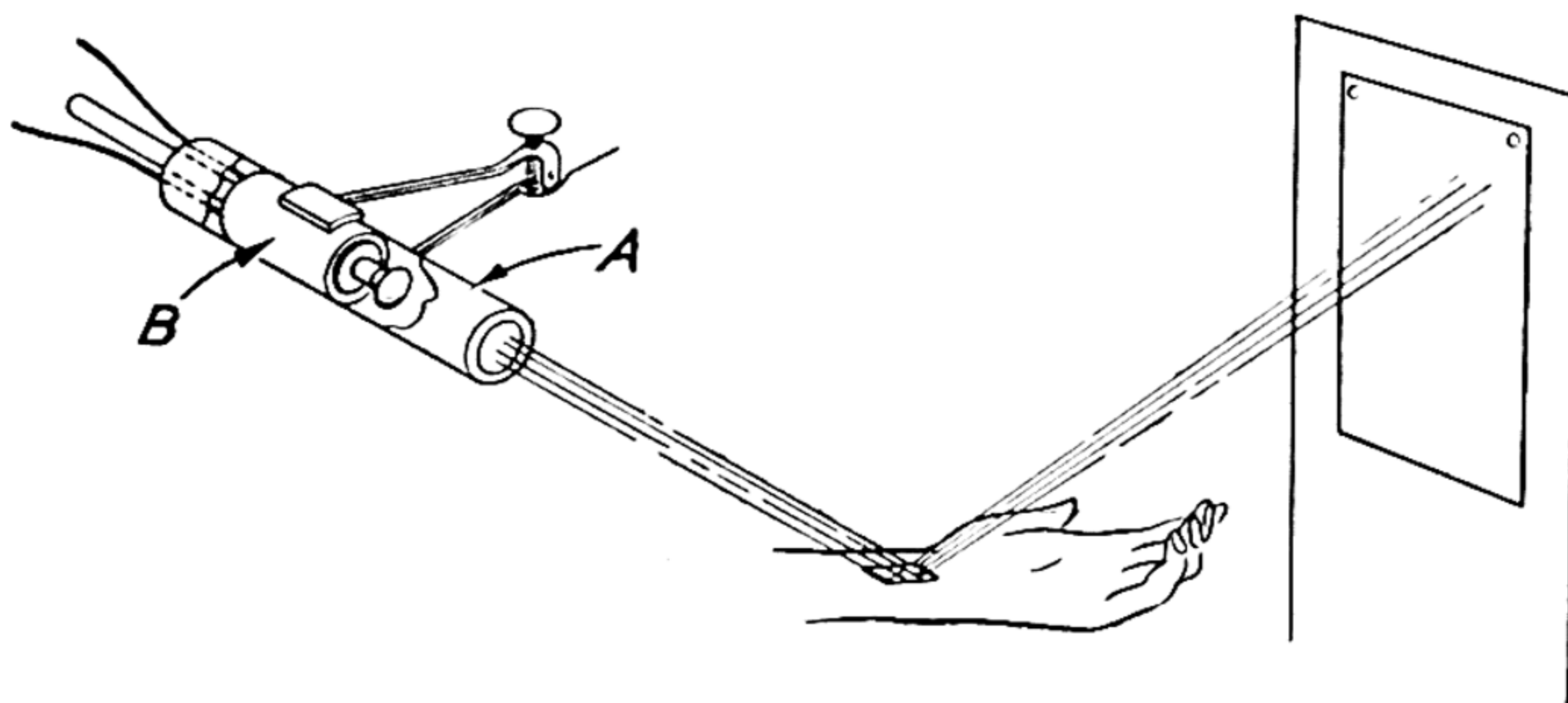


FIG. 119. PULSOMETER

drilled through *B*. The length of the tube *A* depends on the focal length of the lens available, as the lamp must be moved inside *A* until it is at the principal focus of the lens. A narrow parallel beam of light then emerges from the lens.

Graphoscope

A simple form of graphoscope, or copying apparatus, by means of which accurate copies of maps, pictures, diagrams, etc., can be quickly made, is illustrated in Exercise 106, *Everyday Science Topics*, Book II.

A home-made microscope lamp, consisting of a 12-volt lamp in a cylindrical tin supported on a stand, so as to be adjustable, as illustrated in Fig. 120, is excellent for illuminating the picture to be copied. *A*, *A* are pieces of brass soldered to the sides of the tin and held to the piece of wood *B* with a wing-nut and bolt. *C* is a piece of brass fixed with screws to *B* and, with a wing-nut and bolt, to the piece of wood *D*. When the wing-nut holding *C* is loosened the piece of wood *B* can be moved up or down.

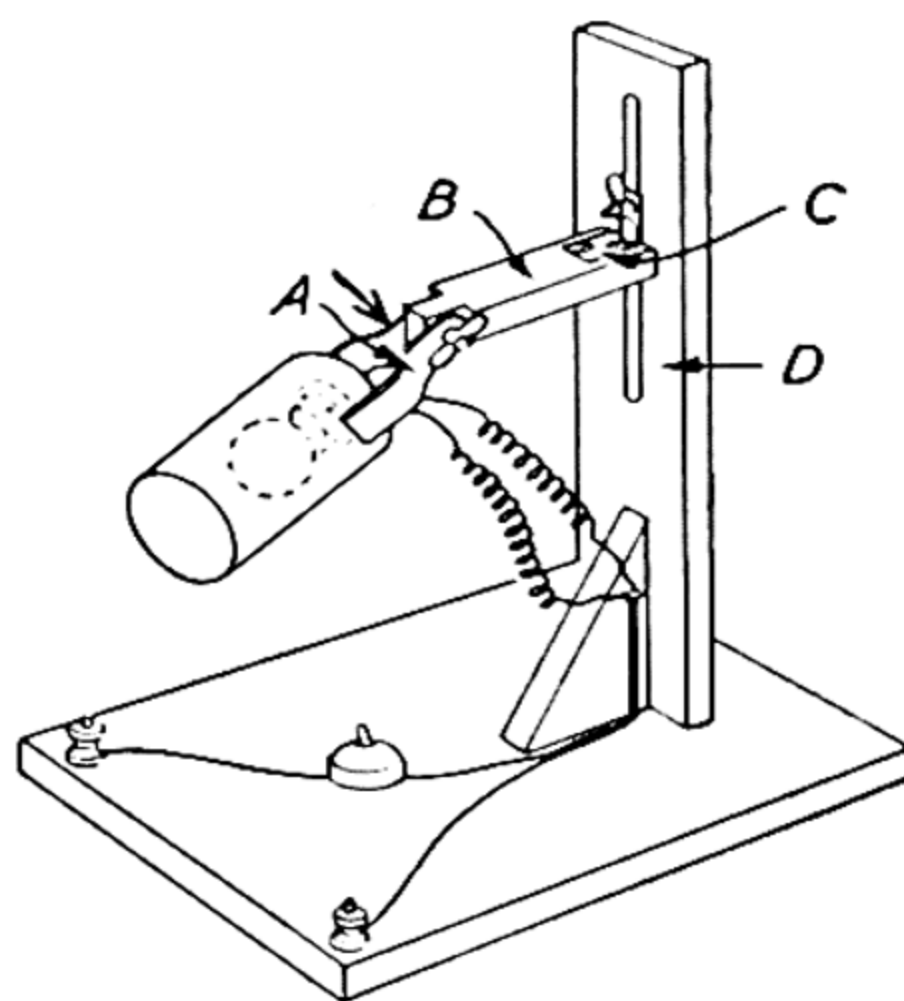


FIG. 120. MICROSCOPE LAMP

When using the graphoscope, the paper on which the copy is to be made is placed on the right-hand side, and as little light as possible should fall on this side. When making the copy, look through the glass from the side of the diagram or picture which is to be copied. The image will be seen on the paper and can be traced out with a pencil which can also be seen quite clearly. If the apparatus is to be used by a left-handed person the arrangement is reversed.

It is important to notice, of course, that copies of diagrams and pictures which are not bilaterally symmetrical are rendered useless by lateral inversion. This can be overcome by placing under the paper on which the copy is being made a piece of carbon paper with the carbon surface next to the underside of the paper. When the copy is completed the correct drawing will be found on the under surface of the paper.

By using the same arrangement of apparatus as that illustrated in Exercise 102, *Everyday Science Topics*, Book II, it can be demonstrated quite easily that when a mirror turns through a certain angle a reflected ray of light turns through twice this angle.

Any position of the reflected ray and the diameter along which the mirror *D* is placed are clearly marked on the large sheet of white paper on which the apparatus is placed. The mirror is then turned through a small angle by turning the card, which has a pin through it at *E*. The new positions of reflected ray and diameter are marked. The card and mirror *D* are removed, and the lines marked are produced until they intersect. The angle between the first and second positions of the reflected ray will be found to be twice as great as the angle between the first and second positions of the diameter along which the mirror was placed.

Other Smooth Surfaces as Reflectors

Some reference has already been made to the glare produced by reflection from white glazed paper. A model to demonstrate this was illustrated in Exercise 32, *Everyday Science Topics*, Book II.

A method of demonstrating reflection from the surface of water is illustrated in Fig. 121. *A* is the spotlight projector, already described and illustrated, with a cardboard ring having a small central hole about $\frac{1}{4}$ in. diameter stuck over the lens to narrow down the beam of light. *B* is a shallow rectangular glass dish filled with water, to which a little fluoresceine is added. The dish is supported on a retort-stand ring. *C* is a piece of white paper, which acts as a screen.

A beam of light is projected on to the surface of the water from position *A*₁. The addition of fluoresceine to the water enables the observer to see the path of the light through the water. A high

percentage of the light is reflected as from a plane mirror and forms the small circle of light, *D*, on the screen. The path of the light through the air can be made apparent by holding a piece of smouldering rag or brown paper near the bench. A small percentage of the

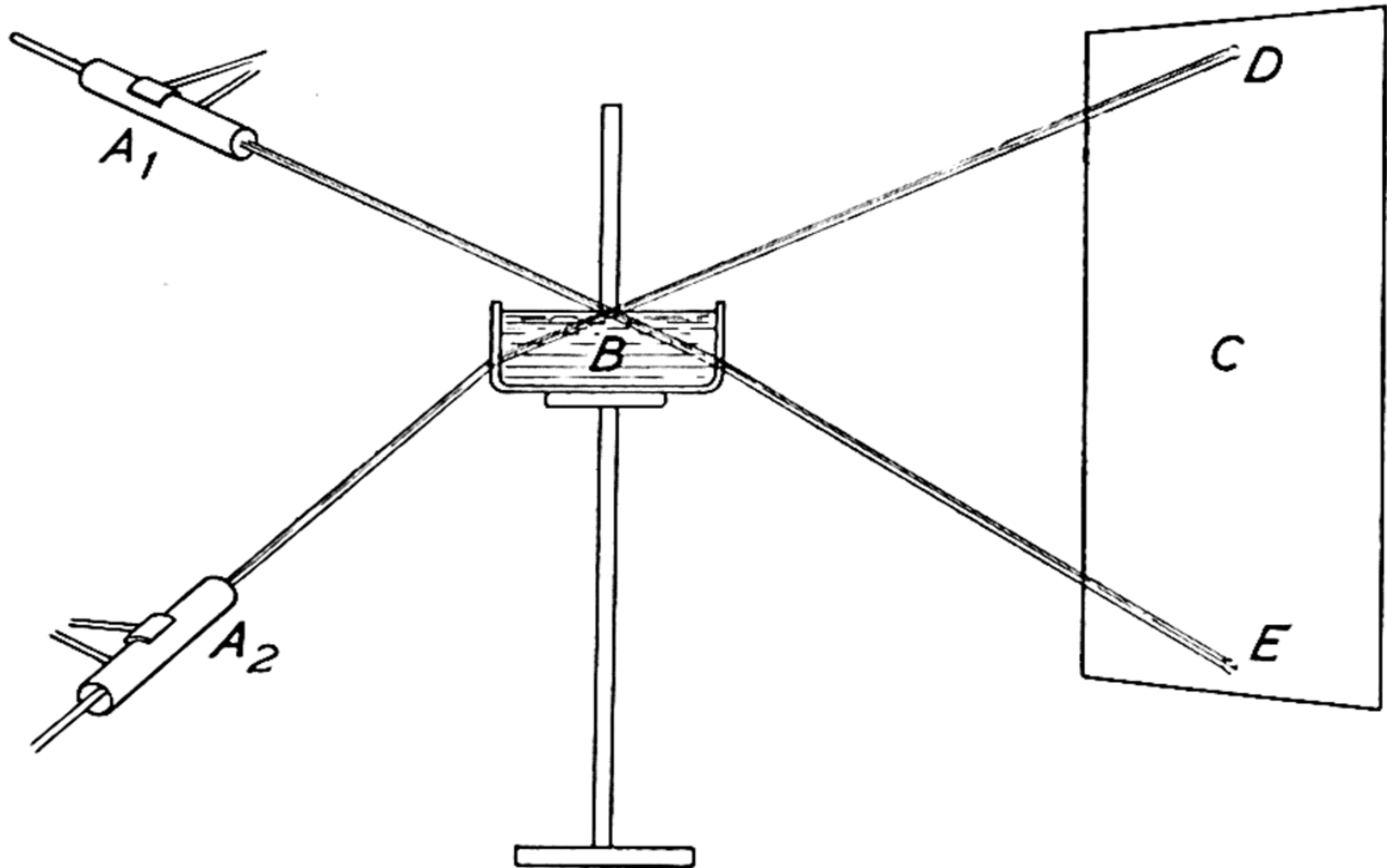


FIG. 121. DEMONSTRATING REFLECTION FROM THE SURFACE OF WATER

light passes into the water, is refracted, and forms a small circle of light at *E*.

A position of the spotlight projector, *A*₂, can be found in which the light enters the water, is totally reflected from its surface, and gives rise to a circle of light at, or near, *E*.

Non-reflecting Shop-window

Most pupils are aware of the disadvantage of the usual type of shop-window of producing images, under certain conditions of illumination, of objects in front of the window. These images interfere with vision of objects displayed in the window. This disadvantage, and a method of overcoming it, can be demonstrated by using a fairly large wooden box, the inside of which is painted dead black. The box is placed on its side, and the open end is covered with a sheet of glass. An object is placed in the box, and it will be found very difficult to see it, on account of reflections, in the box, of outside objects.

The sheet of glass is removed, and over the open end of the box is placed a frame (Fig. 122) holding two curved pieces of Perspex. The whole of the inside of the wooden frame is painted dead black.

The object in the box can be plainly seen, and, indeed, for certain positions of the eye there would appear to be no window at all. Pupils' attention should also be drawn to the unpleasant reflection from the glass in pictures, which sometimes makes it impossible to see the picture.

An important use of plane mirrors for correcting the transposition of a picture from left to right in certain types of episcopic projection is dealt with in Chapter VI, on School-made Optical Aids.

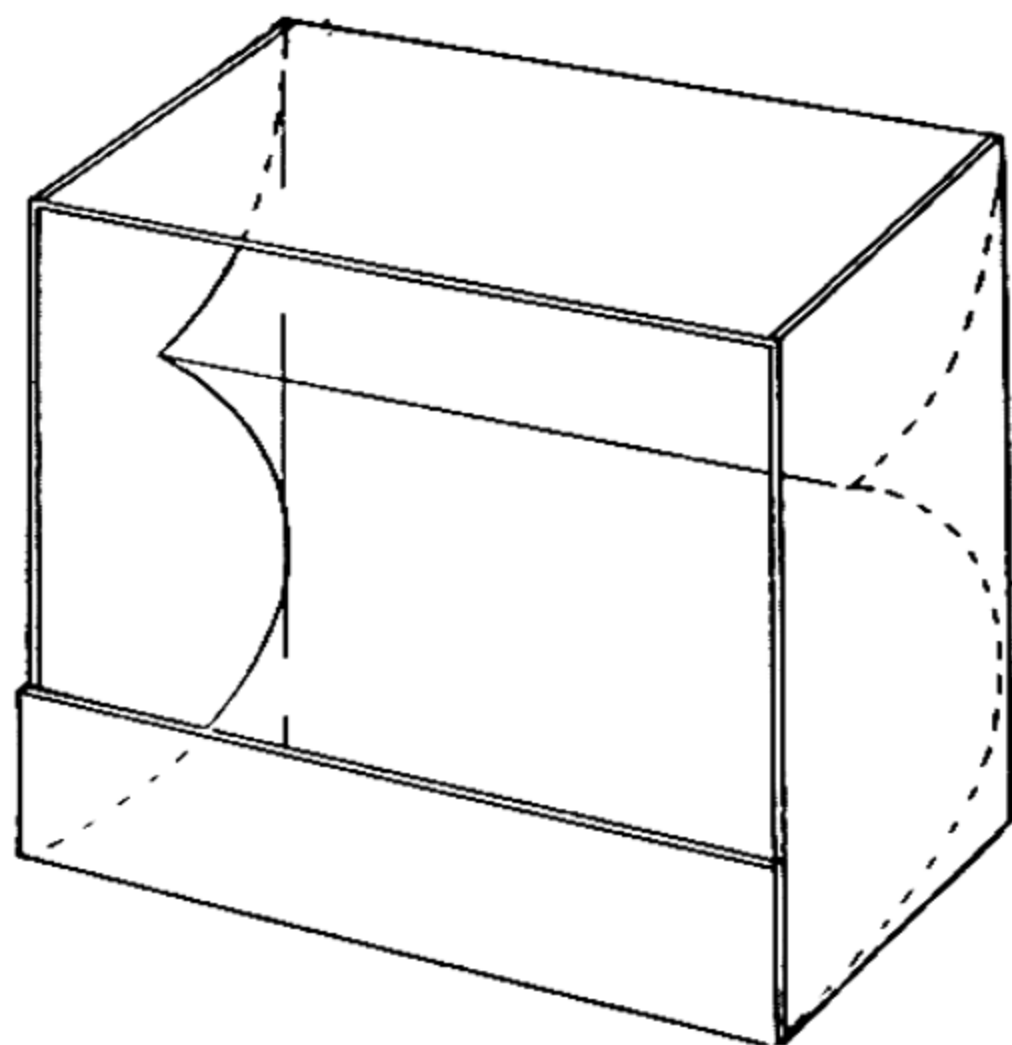


FIG. 122. MODEL OF NON-REFLECTING SHOP-WINDOW

Reflection from Mirrors at an Angle

The illustration in Exercise 110, *Everyday Science Topics*, Book II, shows a piece of apparatus which is very useful for revealing the number and arrangement of the images of an object placed between two mirrors inclined to each other at various angles. A very suitable object is a lighted candle or small electric lamp.

A and *B* are two mirrors with wooden frames. These are hinged together, and can be inclined to each other at various angles by setting them along the lines, marking 5° intervals of space, on the horizontal plywood board *C*. When the angle between the mirrors is 120° two symmetrically arranged images can be seen; when the angle is 90° three images are visible; and so on. When the angles between the mirrors are 120° and 90° a piece of red colour-filter, placed to the right of the candle or lamp, and parallel to the mirror, and a piece of green or blue colour-filter placed to the left and parallel to the other mirror, gives a most interesting result.

The reflections from two parallel mirrors can be observed by removing the hinges and placing the two mirrors parallel to each other. A small electric lamp is placed between the mirrors. To the left of the lamp a small piece of red colour-filter may be placed, and to the right a piece of green or blue colour-filter.

Kaleidoscopes

See Exercise 111, *Everyday Science Topics*, Book II.

A projection kaleidoscope, by means of which beautiful coloured patterns can be projected on to the ceiling, can easily be improvised

if an optical lantern, which can be used in a vertical position, is available. Instead of a lantern-slide a piece of glass, on which are placed a few pieces of different-coloured colour-filter, is used.

Two rectangular pieces of mirror and a piece of cardboard, painted dead black, are cut so as to fit tightly into the objective, and

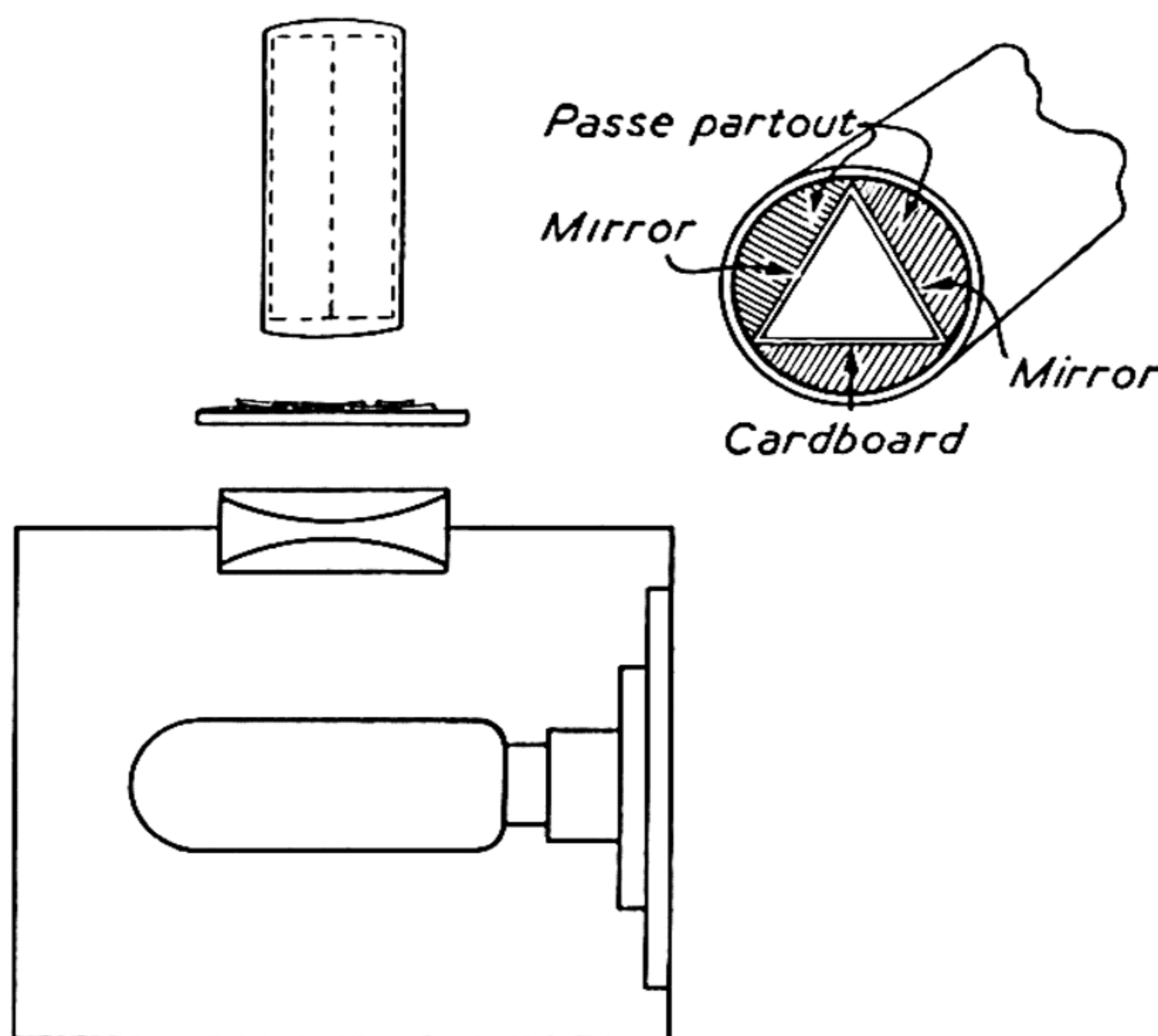


FIG. 123. PROJECTION KALEIDOSCOPE

those parts of the lens nearest to the condenser which are shaded in the sketch are covered with *passe-partout* to prevent light from passing behind the mirrors.

Curved Mirrors

Second-hand parabolic reflectors from motor-car headlamps can usually be obtained from garages or places where worn-out cars are broken up. The manner in which these project a faint diverging beam of light immediately in front of the car and a powerful parallel beam can easily be demonstrated.

A method of demonstrating the action of parabolic reflectors, using a strip of brass or tin plate, was described earlier under Topic (G).

By making the strip of tin or brass plate cylindrical it can easily be demonstrated how the parallel beam becomes divergent.

With the eye very near to a concave shaving-mirror an enlarged image is formed. As the face moves away from the mirror the image

of the eye disappears. This is the magnified virtual image, which is so helpful to the shaver. When the image just disappears measure the distance of the face from the mirror; this gives the focal length of the mirror.

Using the same concave mirror and the apparatus illustrated in Exercise 112, *Everyday Science Topics*, Book II, it can be shown that when there is no image behind the mirror it is in front, and can be reflected on to a screen. This is called a real image.

With a convex motor-car mirror it will be seen how the image is always behind the mirror whatever the position of the object, and that the image is always diminished.

Crazy Mirrors

A method of making a combined cylindrical concave and a cylindrical convex mirror from a sheet of brass plate about 2 ft. square is illustrated in Exercise 113, *Everyday Science Topics*, Book II.

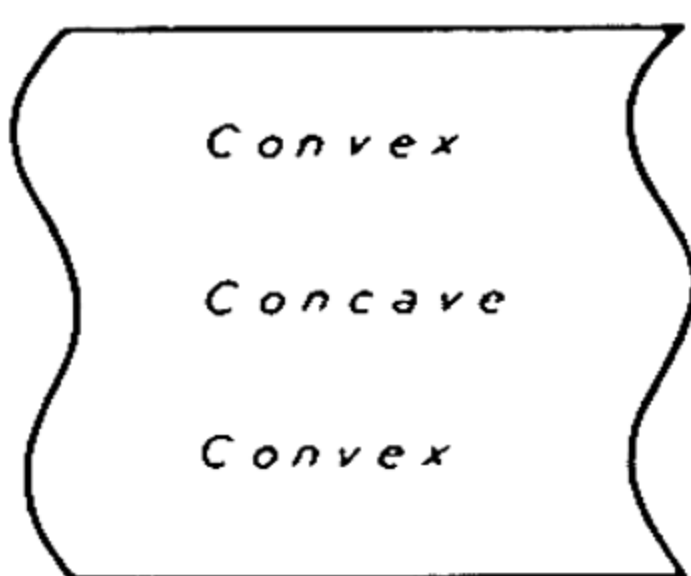


FIG. 124. POLISHED BRASS BENT TO FORM A CRAZY MIRROR

The brass plate is held against the wooden frame, consisting of two uprights and two cross-pieces, each with one curved surface, by means of Meccano angle-brackets fixed to the frame with screws. In this way the brass plate is not damaged, and may be returned to the metal-work department after use. The front surface is a cylindrical concave surface, and the back surface is a cylindrical convex surface. Both

surfaces should be well polished with metal polish, and the apparatus should be used in an upright position or on its side.

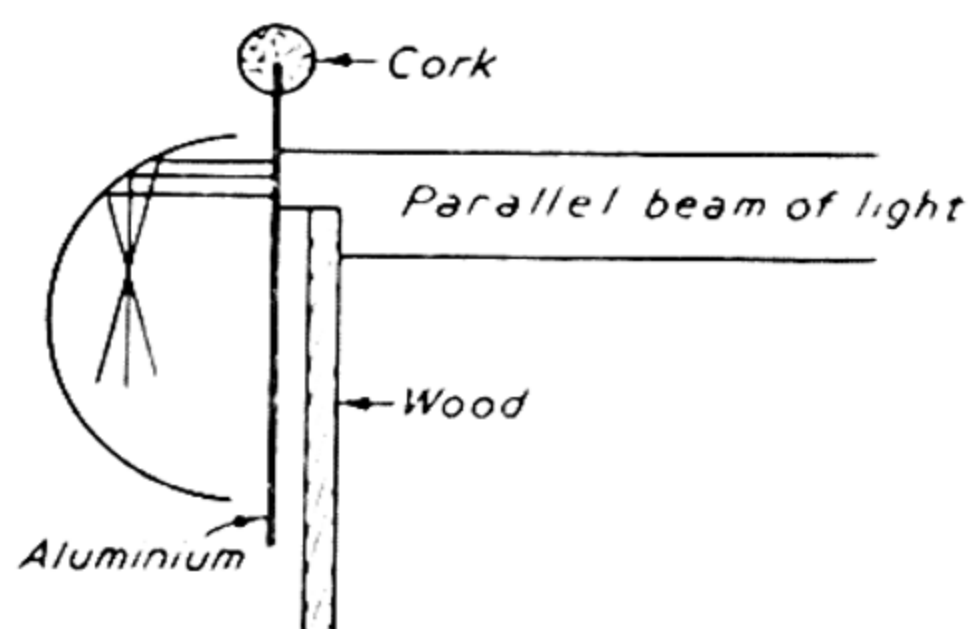
As with the spherical concave mirror, the cylindrical concave side gives an image which can be seen only behind the mirror, when the object is placed between the principal focus and the mirror. The convex side gives an image behind the mirror whatever the position of the object. The types of images seen, which never fail to create amusement, are illustrated in Fig. 2 in the same Exercise.

A most amusing effect can be produced by using as a mirror a sheet of polished brass bent into the shape shown in Fig. 124.

Spherical Aberration

Some reference has already been made to a demonstration of this phenomenon in connexion with the reflection of light from a cylindrical mirror. The formation of a caustic curve of light by reflection from a curved mirror, as seen on the surface of a cup of tea, can be demonstrated by using the apparatus *A* and *B* shown in

Exercise 102, *Everyday Science Topics*, Book II, for producing a parallel beam of light, a piece of wood, a piece of aluminium with a number of parallel vertical hack-saw cuts, and a cylindrical strip of brass plate well polished. Fig. 125 shows the arrangement of the wood, aluminium, and brass strip, and the reflection of the narrow beams of light which pass through the slits in the aluminium as the wood is moved across. The experiment should be repeated with a brass strip in the form of a parabola to show how the reflected rays all pass through the focus.



The first section of the film *Optical Instruments* (16 mm., silent, 1 reel) (Wallace Heaton, Ltd) is excellent for use in connexion with this topic.

For further experiments and models on this topic see pp. 136–149, *Everyday Science Topics*, Book II.

FIG. 125. TO DEMONSTRATE THE FORMATION OF A CAUSTIC CURVE OF LIGHT

(S) Microscopes

This topic can be the source of much valuable and interesting discussion, demonstration, and study.

I cannot imagine a more delightful introduction to this work than a reading of the chapter on Leeuwenhoek, first of the microbe-hunters, in Paul de Kruif's entirely irresistible book, *Microbe Hunters*. The films *Under the Microscope* (16 mm., silent, 1 reel) (Educational Films Bureau) and *Microscopic Animal Life* (16 mm., silent, 1 reel) (Wallace Heaton, Ltd) also serve as good introductory films.

A good supply of suitable convex lenses, magnifying glasses, reading-lenses, and pocket magnifiers should be obtained.

Pupils should first of all observe how convex lenses form images of illuminated objects. By placing a convex lens between a window or an electric lamp and a sheet of white paper, the image of the window or lamp can be seen on the paper by adjusting the position of the lens.

A Simple Optical Bench

For investigating the nature of the images formed by a convex lens, the simple optical bench shown in Fig. 126 can be used to show the formation of real images—that is, images which can be seen on a screen. It is a good plan to mark the focal length of each lens on a piece of stamp-edging stuck to the edge of the lens. This can best be done on a day when the sun is shining by measuring the distance

between the lens and the tiny spot of heat and light formed at the focus.

With the screen *A* at a distance from the lens greater than twice its focal length, an inverted and diminished image is formed on the white screen *B*. With *A* at a distance equal to twice the focal length, the image is inverted and the same size as the object. With *A* at a distance less than twice the focal length but greater than the focal length, the image is inverted and magnified. When *A* is at a distance less than the focal length of the lens no real image can be seen. *D* is an arrow cut out from a piece of sheet brass and covered with translucent paper. The whole fits over an opening in the plywood screen *A*.

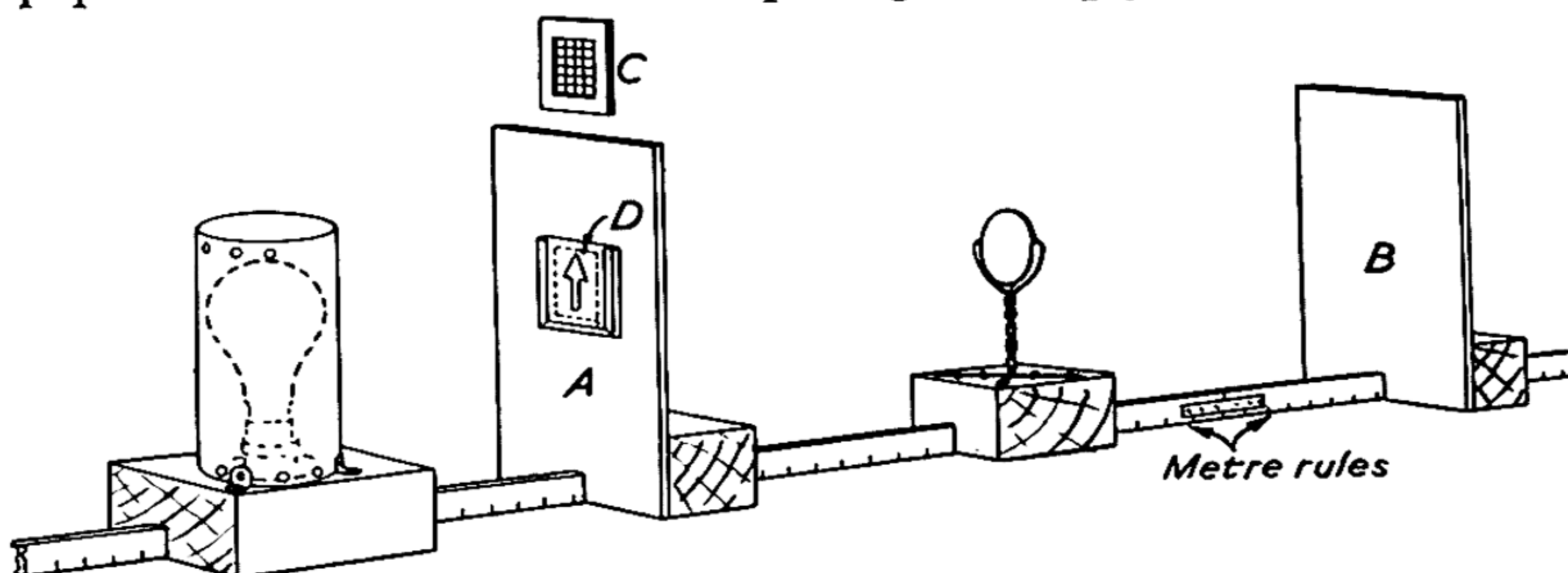


FIG. 126. SIMPLE OPTICAL BENCH

In the latter case, if the screen *B* is removed and the eye is placed very close to the lens, an erect and greatly magnified virtual image of the arrow-head in *A* can be seen on the same side as *A*. When *A* is moved still closer to the lens the image moves up towards the lens. If *A* is placed nearer than a certain distance from the lens the image becomes indistinct, because it is within the least distance of distinct vision (about 25 cm.). In this case the lens is being used as a magnifying glass or simple microscope.

Improvising Simple Microscopes—Defects of Lenses

Simple microscopes can be improvised in several interesting ways, and these always stimulate much interest. A cylindrical glass bottle, a glass tube, or a round flask, filled with water, a drop of water on the upper or under side of a microscope slide, a glass bead formed on the end of a piece of glass tubing, a borax bead formed in a loop of platinum wire, a clear glass marble from a lemonade bottle, a glass bulb on the end of a piece of glass tubing filled with water, or the lens from a bullock's eye, may all be used as crude forms of the simple microscope.

The unsatisfactory images formed by the above improvised magnifying glasses may lead to a discussion of the defect common to all lenses, and to methods of reducing it. The effects of this defect—namely, spherical aberration—may be demonstrated with the optical bench, using a fairly large-diameter convex lens with a short focus. It will be impossible to form a well-defined image on the screen *B* of the object *C*, which consists of cross-wires composed of fine wire held in a brass framework to fit over the opening in the plywood screen *A*. It will also be impossible to see a good virtual magnified image.

It can be shown with the same apparatus that this defect is not so serious when long-focus lenses are used, and that it can be reduced to any required degree by using diaphragms. These can be improvised by covering all the lens, except a small central circle, with a black paper ring. The definition of the image will be improved, but there will be considerable loss in brilliancy. Remove the black paper ring, and, without altering the position of the lens (which should be a large-diameter lens), cover its centre with a large circle of black paper. The image of the cross-wires will now be indistinct, and the screen will have to be moved to make the image sharp again. This demonstrates clearly that rays passing through the edges of a lens do not give an image in the same place as the rays passing through the centre of a lens.

It may also be shown how spherical aberration can be diminished by using plano-convex lenses as simple magnifying glasses, instead of double convex lenses; and by using a pair of plano-convex lenses with convex surfaces together, and each of longer focus, so that their combined focus is equal to that of a shorter-focus lens.

For the above experiments a dark room and a powerful source of light (100-watt pearl electric lamp) are essential. During these experiments another defect of lenses becomes apparent—namely, the coloured edges of the images formed. This is due to chromatic aberration. Some understanding of these defects of lenses and the great difficulty of entirely eliminating them is absolutely essential if pupils are to understand the reason for the complicated nature of some lens systems and the consequent high price of microscopes.

The effects of chromatic aberration may be shown with the optical bench, using object *D* and a short-focus double convex lens. With the screen *B* in one position the image of the arrow-head will have a red border, while farther away it will have a violet border. The reason for these coloured images will be clear, remembering the effect of a glass prism on a beam of light, and noting that a double convex lens is very much like two prisms placed base to base.

Armed with this knowledge, pupils may now proceed to examine the construction of such compound microscopes as are available in the laboratory.

Model Compound Microscopes

A simple home-made microscope giving a power of about 120 is illustrated in Exercise 116, *Everyday Science Topics*, Book II. Pupils working in groups can quite easily make a number of these.

More elaborate objectives and eyepieces can be fitted to the model

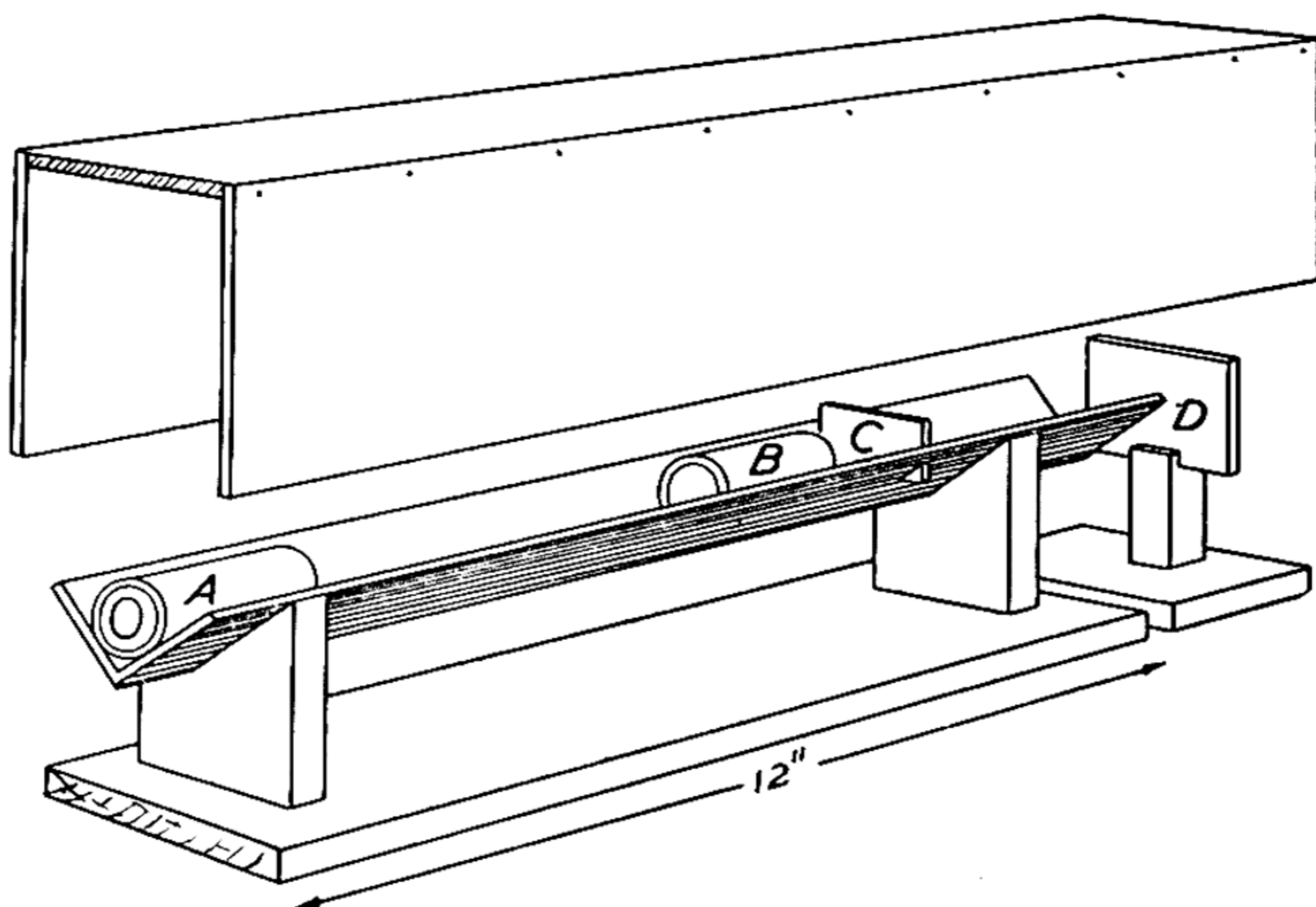


FIG. 127 (a). BUILDING A DEMONSTRATION COMPOUND MICROSCOPE

by adapting the length of the tube *A*; they can be obtained from M. W. Dunscombe, Ltd, 5 and 7 St Augustine's Parade, Bristol, and Broadhurst, Clarkson and Co., Ltd, 63 Farringdon Road, London, E.C.1.

Another method of building up a compound microscope is shown in Fig. 127 (a). It can be used as a piece of demonstration apparatus, not only for assembling quickly a compound microscope, but also for the various forms of telescopes. Pupils see clearly the nature and position of the component lenses and stops, and when the apparatus is assembled it works.

The trough is made of plywood fixed to a wooden stand. *A* and *B* are pieces of ebonite tube which hold the lenses, as illustrated in detail in Fig. 127 (b). The whole of the trough and stand should be painted dead black with a solution of lamp-black and shellac in methylated spirit. Fig. 127 (a) also illustrates a cover, the inside of

which is also painted dead black. This cover is placed over the trough and stand, when the lenses have been placed in position, to cut out extraneous light. *C* is a microscope slide, and *D* is a piece of plane mirror placed in such a position that it reflects light (from the model microscope lamp, previously described in the section on mirrors) on to the slide.

For Fig. 127 (*b*) I have given the actual sizes and focal lengths of lenses I use, but, of course, other suitable lenses can be used. The ebonite tube has the advantage of having a dead-black surface inside, and the Economic Electric Company, 64 London Road, Twickenham, can supply lengths of the tubing *E* (1½ in. inside diameter) and *F* (1¼ in. outside diameter), so that one is a good fit inside the other.

G is a plano-convex lens, 2 cm. diameter and 35 mm. focus. *K* is a plano-convex lens, 3 cm. diameter and 5 cm. focus. *H* is a stop, made from a disc of sheet brass with a hole in the centre 15 mm. in diameter, and painted dead black. The distance between *G* and *K* should be about 3 cm. *L* is a plano-convex lens, 15 mm. diameter and 3 cm. focus. Both *G* and *L* are fixed in holes bored in large corks. The distance between *L* and *K* should be about 13 cm., and the distance between *L* and the slide *C* should be about 4 cm. Suitable lenses can be obtained from the cheap stores or from the firms already mentioned.

By interposing a piece of ground glass or translucent paper between *A* and *B*, and fairly near to *A*, the formation of a magnified real image can be observed.

Any short-focus plano-convex lens will serve as an objective. A Huygens eyepiece can be built up as illustrated here, in which case fairly short-focus lenses are used, and the focal lengths of the field and eye-lenses should be approximately in the ratio 3 : 1, while the distance between them should be approximately equal to twice the focal length of the eye-lens.

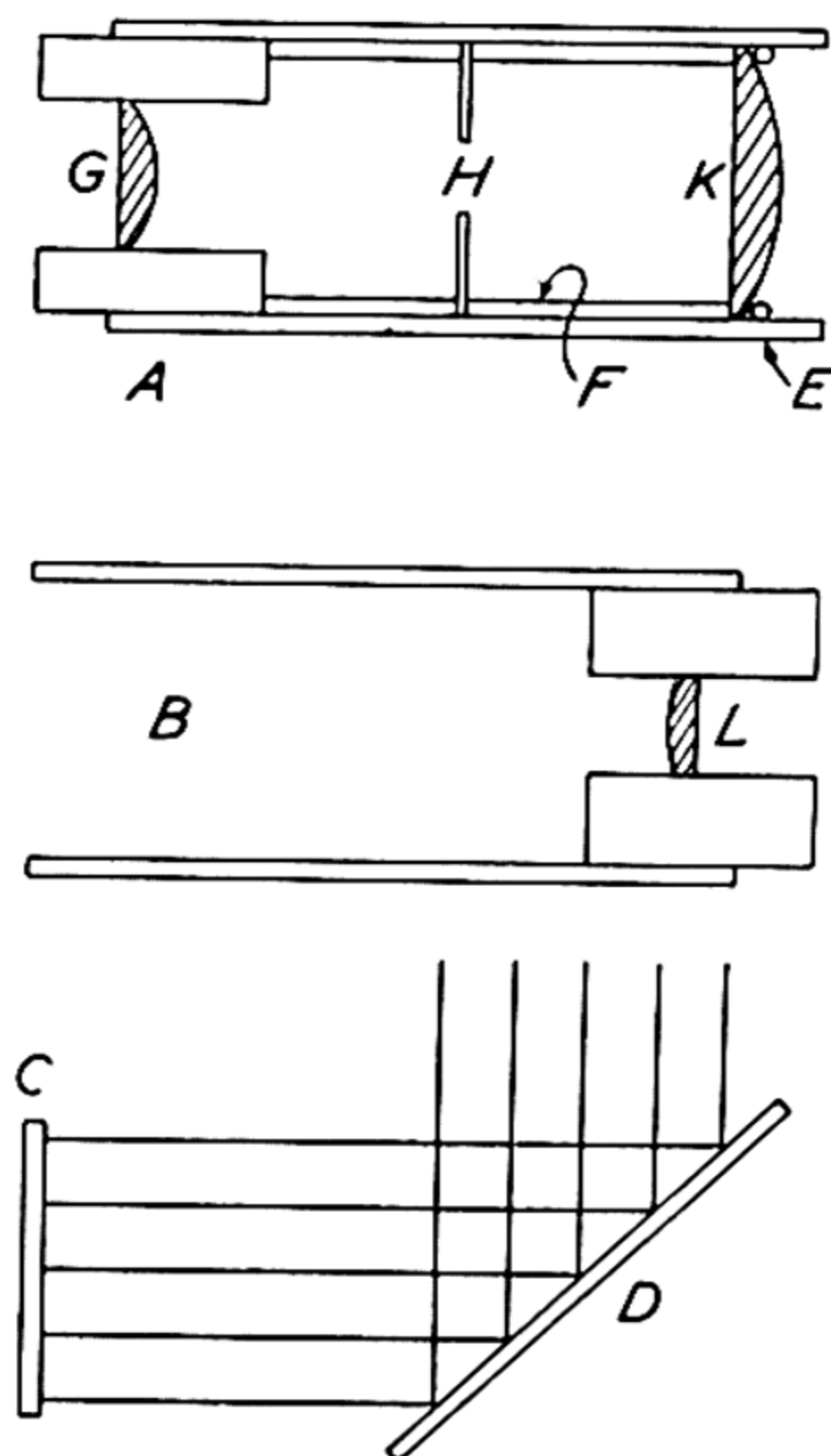


FIG. 127 (*b*). BUILDING A DEMONSTRATION COMPOUND MICROSCOPE

A Ramsden's eyepiece can be constructed by using two plano-convex lenses of equal diameter and equal focal lengths, with convex surfaces facing each other, and separated by a distance equal to two-thirds of the numerical value of the focal length of either. Again short-focus lenses should be used.

Apparatus to show the Action of the Lenses in a Microscope

The apparatus illustrated below can be used to demonstrate the paths of the light waves through a microscope. The light converging

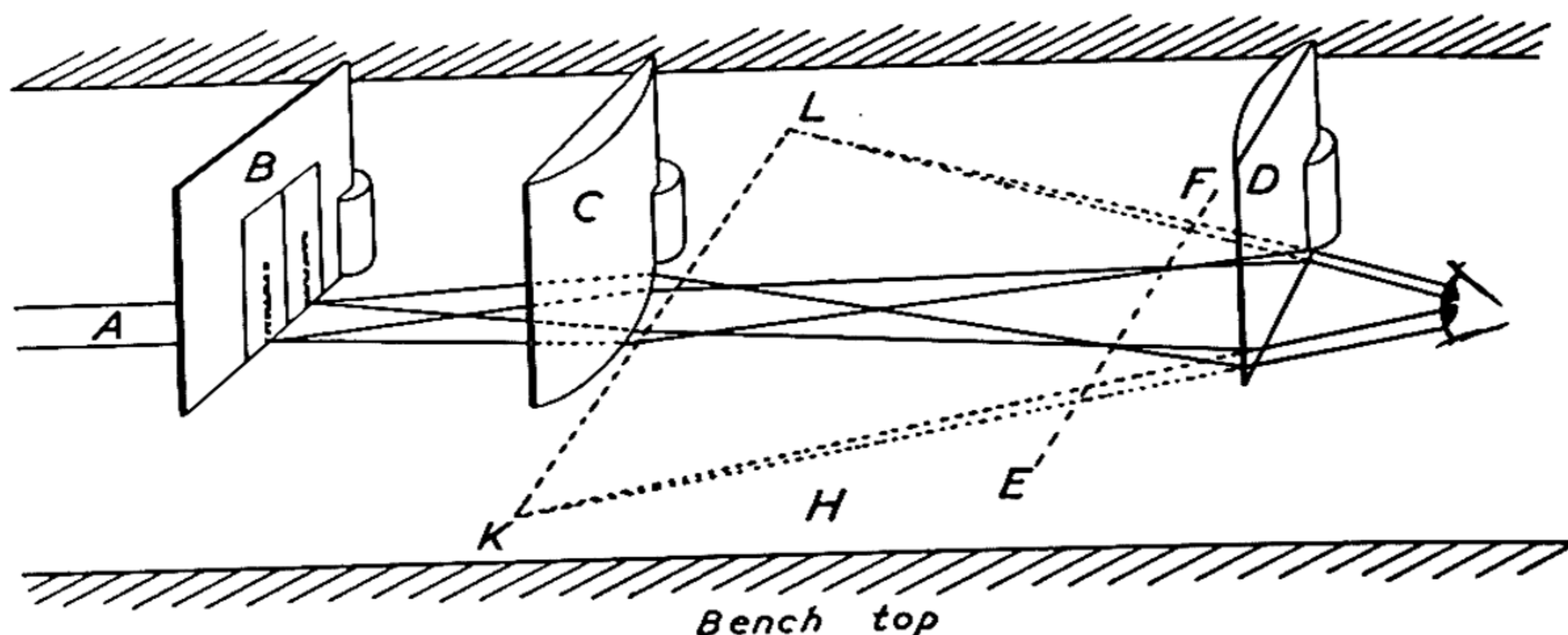


FIG. 128 (a). TO SHOW THE ACTION OF LENSES IN A MICROSCOPE

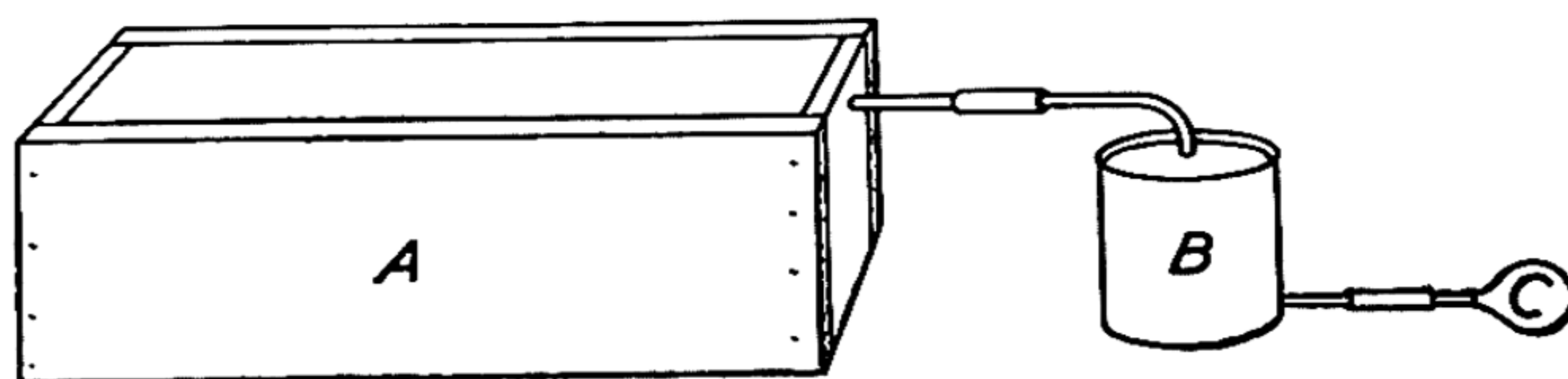


FIG. 128 (b). SMOKE BOX

to form a real image in the body of the microscope, and diverging from a virtual image after passing through the eyepiece, can be clearly demonstrated.

The same thing can be shown by surrounding the apparatus illustrated in Fig. 128 with a smoke-tight box, painted dead black inside, and having a glass panel in the top for observation purposes. A method of forcing smoke into the box, from a smouldering turpentine rag in a treacle-tin, is shown in Fig. 128 (b). *A* is the smoke-tight box, *B* is the treacle-tin, and *C* is a rubber bulb from a scent-spray.

In Fig. 128 (a) the parallel beam of light *A* is produced by parts *A* and *B* of the apparatus illustrated in Exercise 102, *Everyday Science*

Topics, Book II; *B* consists of a piece of sheet brass painted dead black on both sides and having two narrow vertical slits cut in it with a hack-saw. One of the slits is covered with a piece of red colour-filter and the other with a piece of blue colour-filter, and the piece of brass is held in a vertical position by pushing it into a slit made in a cork. Sheets of colour-filters can be obtained from the Strand Electric Company, Ltd, 19-25 Floral Street, Covent Garden, London, W.C.2.

C is a plano-convex cylindrical lens, with its plane surface towards *B* and situated at a distance from *B* slightly greater than its focal length, which may be about 6 cm. If a piece of white card is placed vertically at *EF*, real images of the slits in *B* can be seen with the distance between them magnified, and the paths of the light forming these images can be seen on the white card, *H*, placed on the bench top.

If the white card at *EF* is removed and the light allowed to pass on to the lens *D*, so placed that the real images at *EF* are at a distance from *D* less than its focal length, then, after passing through *D*, the light will be seen to be coming from virtual images of the slits at *K* and *L*, and these can actually be observed on looking into *D*.

Suitable plano-cylindrical lenses of best white optical glass can be obtained from M. W. Dunscombe, Ltd.

Films

The following films contain sections on the action and uses of lenses and the microscope:

The Transmission of Light through a Convex Lens (16 mm., silent (50 ft. length or continuous loop film)) (Dance-Kaufmann Technical Films).

Lenses (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Microscopic Animal Life (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Optical Instruments (16 mm., silent, 1 reel) (Wallace Heaton, Ltd).

Optical Glass (16 mm., silent, 2 reels) (Cine Equipments, Ltd).

The looped films are cheap, and they can be used in any silent projector. It is necessary to carry the loose coils of the loop on a device called a "loop-absorber," which prevents the coils from becoming entangled. A method of improvising a loop-absorber is illustrated in Fig. 129. *A, A* are retort stands, and *B, B, B, B* are wooden bobbins of the type used for holding insulated wire. The empty bobbins are held with nuts and bolts so as to rotate freely. Loop films as long as 50 ft. are unusual, and, in this case, three or four stands and pairs of bobbins might be necessary. The stands will have to be placed out of the path of the light from the objective.

Some loop films are only about 2 ft. long, and in this case one wooden bobbin held on a retort stand is enough to support the loop. These loop films are an important type of film, illustrating small elements of action for detailed examination and study. They can also be obtained from Cinepro, Ltd, 1 New Burlington Street, London, W.1.

Picture postcards, lantern-slides, and photographs illustrating different kinds of microscopes and their development can be obtained from the Science Museum, South Kensington, London, S.W.7.

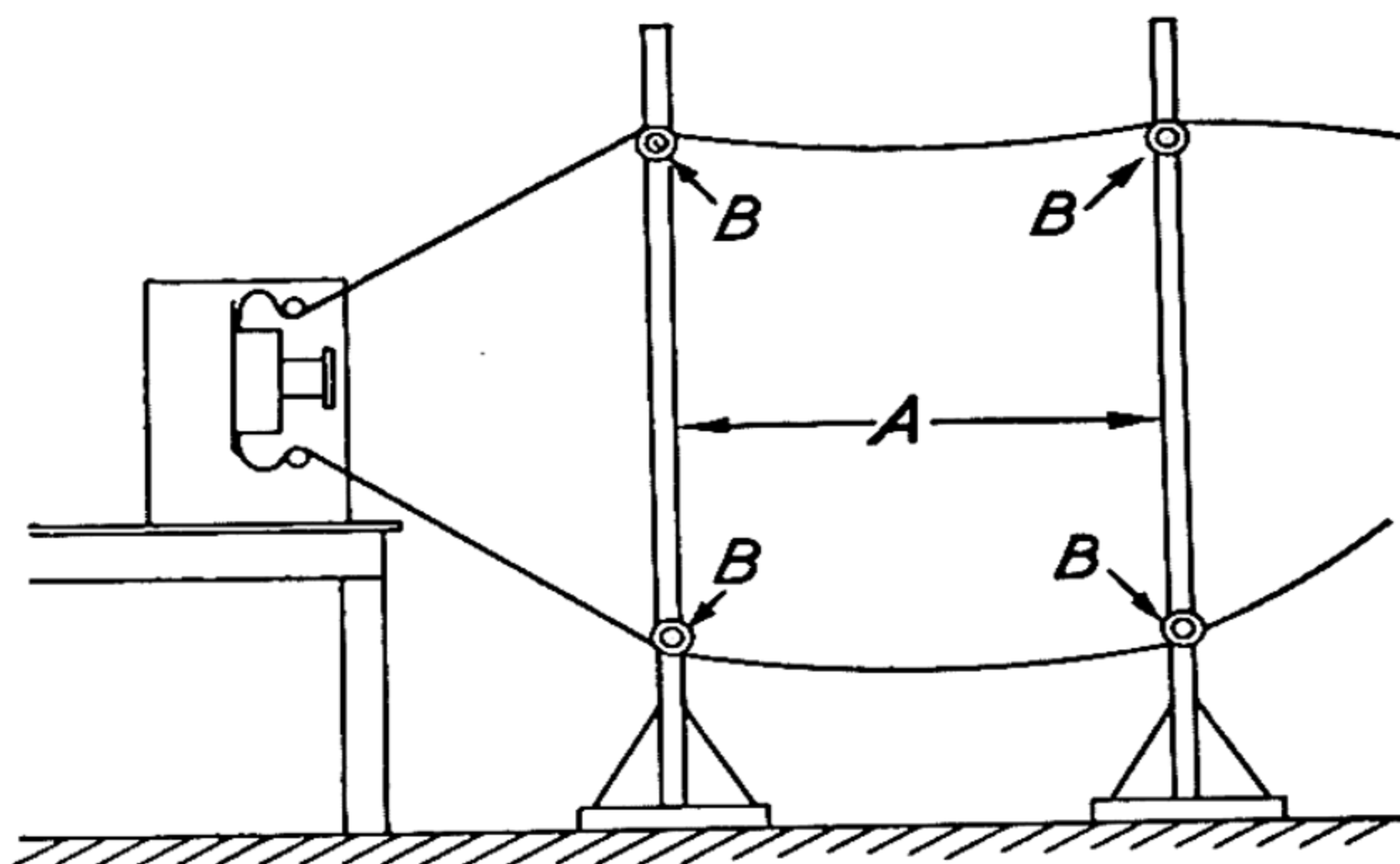


FIG. 129. LOOP-ABSORBER

Picture postcards in monochrome can be purchased for 3d. each, photographs 12 in. by 10 in. cost 2s. each, and lantern-slides are available for loan. Full details of the postcards, photographs, and lantern-slides available for use in connexion with this and other topics can be obtained on application to the Director, the Science Museum.

Mounting Specimens for the Microscope

The examination of common objects, which are often so common as to be ignored, will give a fund of knowledge, and awaken interest in things otherwise taken for granted. In connexion with the section on "Clothing," in Exercise 83, *Everyday Science Topics*, Book II, I recommended the examination of fibres of cotton, wool, silk, etc., through the microscope. These and other specimens should not be crowded. When mounting flat specimens, such as pieces of fabric or wings of insects, the specimen can be placed on one slide, another slide placed on top, and the two slides held together with two rubber bands.

Some objects would be damaged if placed between two glass slides

in this way. A better way is to pass two rubber bands round one slide, and on it place the object. Place a second slide over the top, and hold the two slides together with two more rubber bands.

A live box, suitable for the examination of small insects, can be made by placing a small piece of ebonite tubing about $\frac{1}{2}$ in. in diameter and $\frac{1}{8}$ in. deep on one glass slide, then another glass slide on top, and holding the three together with rubber bands.

A small aquarium for the examination of pond life can be made by fixing to a glass slide a piece of ebonite similar to the above. A watertight joint between the ebonite and glass can be made with paraffin-wax, Plasticine, or gum.

Further Information on Microscopes and their Uses

For use in the secondary-school science room, microscopes supplied by the following firms are quite satisfactory.

Illustrated lists and catalogues, which form excellent additional material for use in connexion with this topic, will be forwarded on request.

W. Watson and Sons, Ltd, 313 High Holborn, London, W.C.1. Pocket pencil microscope; "Wands" microscope.

Hamley Brothers, Ltd, 200 and 202 Regent Street, London, W.1. Microscopes and microscope sets.

Electradix, 214 Queenstown Road, London, S.W.8. Microscopes.

Bausch and Lomb Optical Company, Ltd, Africa House, Kingsway, London, W.C. 2. Microscopes.

Aircraft Products, Ltd, 89-91 New Oxford Street, London, W.C.1. Microscopes.

The following Watson publications will be found most useful:

Catalogue of Microscopes and Accessories, Part I.

Microscopes, Fittings, and Optical Parts, Part 2.

Microscope Accessories, Part 3.

Objects for the Microscope, Part 5.

Photomicrographic and Projection Apparatus.

Second-hand Microscopes and Accessories.

All the above publications contain helpful illustrations and information. See also pp. 150-154 of *Everyday Science Topics*, Book II.

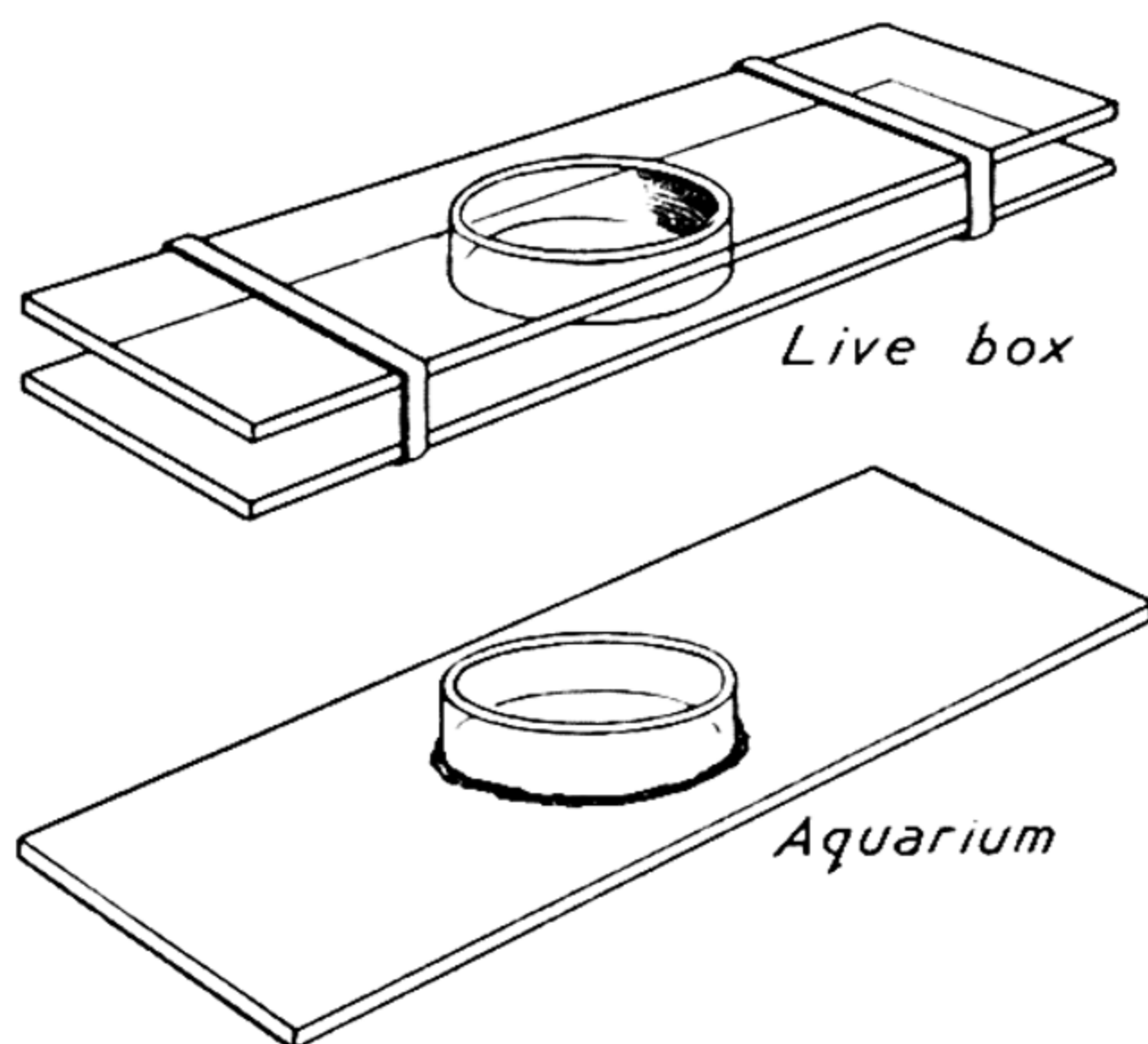


FIG. 130. LIVE BOX AND AQUARIUM

Books on Microscopes and their Uses

- (1) *Adventures with the Microscope*, given free with the Bausch and Lomb Model "R" microscope, or can be purchased separately.
- (2) BECK, C.: *The Microscope. A Simple Handbook.*
- (3) CARPENTER, W. B.: *The Microscope and its Revelations.* (This is the standard work.)
- (4) CROSS, M. I., AND COLE, M. J.: *Modern Microscopy.*
- (5) DAVIDGE, H. T.: *Optical Instruments.*
- (6) DOORLY, E.: *The Microbe Man. A Life of Pasteur for Children.*
- (7) DOWDY, S. E.: *The Microscope. How to choose and use it.*
- (8) HALL, C. A.: *How to use the Microscope.*
- (9) HAWKS, E.: *The Microscope shown to the Children.*
- (10) HEATH, C. E.: *The Beginner's Guide to the Microscope.*
- (11) HEATH, C. E.: *Microscope Slide-making.*
- (12) *Microscope and Entomological Monthly*, published alternate months, price 1s. 6d.
- (13) *Microscope Experiments* (two books), given free with the Bausch and Lomb "Gem" microscope, or can be purchased separately.
- (14) *Origin and Development of the Microscope.* (Includes illustrated catalogue of the Royal Microscopical Society's Collection.)
- (15) *Practical Microscopy*, monthly, 25c.
- (16) ROWLAND, T. J. S., AND SMITH, L. G.: *Vital Things for Lively Youngsters.*

Other books in the series by T. J. S. Rowland, all of which are very popular with children on account of their delightful illustrations, are: *Moving Things for Lively Youngsters*, *Everyday Things for Lively Youngsters*, *Living Things for Lively Youngsters*, and *More Living Things for Lively Youngsters*. All can be obtained from Cassell and Co., Ltd, 37-38 St Andrew's Hill, Queen Victoria Street, London, E.C.4.

- (17) SHIPLEY, A.: *Hunting under the Microscope.*
- (18) WATSON BAKER, W. E.: *The World beneath the Microscope.*
- (19) WOOD, J. G.: *Common Objects of the Microscope.*
- (20) WRIGHT, L.: *A Popular Handbook to the Microscope.*

Books numbered 7, 9, 14, 17, 18, and 19 above may be obtained from W. Watson and Sons, Ltd.

(T) Telescopes

For senior pupils telescopes have the same fascination as they had in 1610 for those people who first learned that with the aid of two pieces of glass and a paper tube distant objects could be brought closer for inspection. Most pupils are familiar with one or other of the various types of telescopes. The cheap stores used to sell them for a shilling or two, and good opera glasses, prismatic binoculars, and terrestrial telescopes are to be found in many homes.

When work on this topic is started an attempt should be made to

collect together a representative collection of telescopes with which to commence work; discussion of the uses of telescopes leads quite naturally to some work on astronomy. The fascination of probing the mysterious depths of illimitable space and examining at closer quarters the many marvels scattered about the sky can be enjoyed with very little technical knowledge and at comparatively small expense.

In the words of the Board of Education's "Suggestions":

Observations must be made out of school hours, and the time available is very restricted, but the children should be taught to recognize the brighter stars and to study the motions of the planets and constellations, and should be encouraged to read some of the many good books on astronomy that are now available.

No treatment of everyday phenomena would be complete without some reference to the sky at night. The aim should be to revive the interest which young children spontaneously show in the heavenly bodies, and to help pupils to get some realization of the majesty and wonder of a common sight.

In many districts there is an enthusiastic amateur astronomer who has set up a really fine telescope, or there may be access to a local observatory. Where a peep at the heavens through a really good telescope can be arranged this serves as an excellent introduction to this topic. The film *A Journey round the Moon* (16 mm., silent, 1 reel) (Educational and General Services, Ltd), giving an excellent impression of the landscape and general conditions on the surface of the moon, also serves as an excellent introductory film. It takes ten minutes to project.

Astronomical Telescopes

Various makes, either new or second-hand, can be purchased from dealers, or through the medium of the exchange and mart columns of certain journals, and great bargains frequently may be picked up in this way.

A suitable refracting telescope should have an achromatic object glass of not less than $2\frac{1}{2}$ in. aperture, and preferably three eyepieces magnifying about 60, 100, and 200 diameters respectively, as well as a 'dark cap' to serve as a protection to the eyes when looking at the sun.

Good second-hand telescopes may often be obtained from the following firms:

C. E. Macket and Co., 51 Millers Road, Brighton.

C. Baker, 244 High Holborn, London, W.C.1.

Broadhurst, Clarkson and Co., 63 Farringdon Road, London, E.C.1.

W. Watson and Sons, Ltd, 313 High Holborn, London, W.C.1.

It is not a very difficult matter to make a telescope capable of revealing the tilted rings of Saturn, the polar caps of Mars, the satellites of Jupiter, and an infinitude of fascinating detail on the moon. Of the 15,000 or so persons in the U.S.A. who have become amateur telescope-makers, a few are women; some are professional people, and others are labourers, students, and housewives. A surprising number have produced excellent telescopes.

Any teacher who contemplates making a telescope should obtain *Amateur Telescope-making*, by A. G. Ingalls (Munn and Co.), and some of the excellent literature issued by the following American firms:

John M. Pierce, 11 Harvard Street, Springfield, Vermont.

Optical Research Associates, Plainfield, New Jersey.

Tinsley Laboratories, 3017 Wheeler Street, Berkeley, California.

Precision Optical Co., 1001 East 163rd Street, New York.

A method of making an astronomical telescope is described in Exercise 118, *Everyday Science Topics*, Book II.

Reflecting Telescopes

The refracting telescope, in which light passes through a lens forming an image that is magnified by the eye-lens, has always been limited in use, due to colour distortion and difficulty in securing glass of suitable optical quality. Sixty years after Galileo, Newton devised the first reflecting telescope. This type is free from many of the troubles of the refractor, for the light is reflected from the surface of a mirror and does not pass through the glass.

Such a telescope, mirror and all, can be readily made at very little cost. With a 6-in. mirror, focal length 50 in., one may explore the sun, the moon, and the planets, bring into view myriads of stars in the Milky Way, and a variety of star clusters and nebulae. Jupiter will be enlarged to the apparent size of the moon, and the moon will increase in area many times, revealing an infinitude of fascinating detail.

Amateurs usually begin with a 6-in. mirror, for with mirrors of greater diameter difficulties in the making increase out of all proportion to the gain in size. The book *Amateur Telescope-making*, the most complete and comprehensive of its type, is a tremendous aid to anyone constructing a telescope. It gives complete detailed

instructions on how to grind, polish, figure, and silver a mirror, and numerous easily constructed mountings are described.

C. E. Macket and Co. of Brighton will supply a $4\frac{1}{2}$ -in. diameter mirror, focal length 36 in., and flat, and two suitable eyepiece lenses. They will also supply a 6-in. diameter mirror, focal length 50 in., and two suitable eyepiece lenses.

A simple method of mounting a mirror and flat to make a reflecting telescope is illustrated in Exercise 119, *Everyday Science Topics*, Book II.

Terrestrial Telescopes, Prismatic Binoculars, Galilean Telescopes, Opera Glasses—where to obtain Them and Information about Them

Catalogues from the following firms always contain particulars of cheap specimens of the above, quite suitable for secondary schools:

Electradix, 214 Queenstown Road, London, S.W.8.

Aircraft Products, Ltd, 89–91 New Oxford Street, London, W.C.1.

C. Baker, 244 High Holborn, London, W.C.1. (List of second-hand scientific instruments.)

Hamley Brothers, Ltd, 200 and 202 Regent Street, London, W.1. (Toy catalogue.)

Broadhurst, Clarkson and Co., 63 Farringdon Road, London, E.C.1. (Lists of second-hand telescopes and binoculars.)

W. Watson and Sons, Ltd, 313 High Holborn, London, W.C.1.

City Sale and Exchange, Ltd, 66 Cheapside, London, E.C.2.

Further Information

Books

BELL, L.: *The Telescope*.

BROAD, C. D.: *Sir Isaac Newton*.

CAMPBELL, W. W.: *Elements of Practical Astronomy*.

CHAPMAN, S.: *Pioneers of Progress—Galileo*.

CORBIN, T. W.: *Astronomy for Boy Scouts and Others*.

DAVIDGE, H. T.: *Optical Instruments*.

Ganot's Elementary Physics, translated by E. Atkinson.

(Published 1881. Gives full details of telescopes of all classes.

Copies are sometimes obtainable at Foyle's.)

HAY, W. T.: *Through my Telescope*. (By the late Will Hay, the mirth-provoking schoolmaster of the variety stage.)

HEATH, R. S.: *Elementary Treatise on Geometrical Optics*.

(Published 1897; may now be unobtainable. It contains some excellent information on the construction of telescopes.)

JEANS, SIR JAMES: *The Stars in their Courses*.

(Written for those who have no previous scientific knowledge of any

kind. It is an introduction—written in the simplest possible language, and illustrated with a large number of photographs—to modern astronomy and to the wonder of the universe as seen through the giant telescopes of to-day.)

LEGGETT, E. B.: *Stars and their Uses*.

LOCKYER, SIR NORMAN: *Primer of Astronomy*.

LODGE, SIR OLIVER: *Pioneers of Science*.

MCKAY, H.: *The Sun and the Moon* ("First Steps in Science" series).

MCKREADY, K.: *Beginner's Guide to the Stars*.

MCKREADY, K.: *Beginner's Star Book*.

MARTIN, M. E.: *Friendly Stars*.

MAUNDER, A. S. D., AND E. W.: *The Heavens and their Story*.

Nautical Almanack.

(Useful when discussing importance of a knowledge of astronomy in navigation.)

PENDRAY, G. E.: *Men, Mirrors, and Stars*.

(An intensely interesting book, of great use in connexion with this topic.)

PROCTOR, M.: *The Book of the Heavens*.

PROCTOR, M.: *Our Stars Month by Month*.

(Illustrated with twelve star charts in envelope.)

PROCTOR, M.: *Wonders of the Sky*.

PROCTOR, R. A.: *Half-hours with the Telescope*.

SOUTHALL, J. P. C.: *Mirrors, Prisms, and Lenses*.

Stars at a Glance (George Philip).

(This is a useful abridgment of a star atlas, giving acquaintance with the principal constellations and their components. A revolving planisphere, which can be obtained for about 2s., is also very helpful. This is a cardboard device by which the aspect of the heavens on any night and at any hour can readily be displayed by merely turning the dial to the required date and time.)

STETSON, H. T.: *Man and the Stars*.

TAYLOR, H. E.: *Wonders of the Universe*.

WARD, F. O. B.: *Handbook of the Collections Illustrating Time Measurement*. (Part I, "Historical Review.") (H.M.S.O.)

(Chapter I deals with "Astronomy and Time.")

WATERS, H. H.: *Astronomical Photography for Amateurs*.

WOOLLEY, R. VAN DER RIET: *A Key to the Stars*.

Helpful Literature

(1) The following publications and photographs given free by Sir Howard Grubb, Parsons and Co., Optical Works, Walker Gate, Newcastle-on-Tyne, manufacturers of some of the world's principal large telescopes, are of particular interest:

Publication No. 1, *Astronomical and Optical Instruments*. (Contains illustrations of telescopes made by the firm and sent to all parts of the world, and information on the development of optical instruments for

astronomy, and the relative advantages of refracting and reflecting telescopes.)

Publication No. 4, *Astronomical and Optical Instruments Catalogue*.

Publication No. 9, *Astronomical and Optical Instruments*.

Publication No. 12, *The 74-in. Reflecting Telescope of the Radcliffe Observatory, Pretoria*.

(Photographs of mirrors in course of construction.)

(2) *Seeing Stars and Portable Telescopes* (Broadhurst, Clarkson and Co.).

Films

A Journey round the Moon (16 mm., silent, 1 reel (10 min.)) (Educational and General Services, Ltd).

Astronomy (16 mm., sound, 1 reel (8 min.)) (Sound Services, Ltd).

(Illustrates the relation of the earth, the moon, and the sun.)

Behaviour of Light (16 mm., silent, 1 reel (12 min.)) (Wallace Heaton, Ltd).

Day and Night (16 mm., silent, 1 reel (12 min.)) (Educational and General Services, Ltd).

Exploring the Heavens (16 mm., sound, 1 reel (8 min.)) (Sound Services, Ltd).

(Shows a visit to the Royal Observatory at Greenwich and an interview with the Astronomer Royal. The great telescope is seen and described.)

Lenses (16 mm., silent, 1 reel (10 min.)) (Wallace Heaton, Ltd).

Optical Glass (16 mm., silent, 2 reels (20 min.)) (National Film Library).

Optical Instruments (16 mm., silent, 1 reel (10 min.)) (Wallace Heaton, Ltd).

Sun, Moon, and Darkness (16 mm., silent cycle film, 16 feet long (for sale only)) (Cinepro, Ltd).

The Solar System (16 mm., silent, 1 reel (10 min.)) (Educational and General Services, Ltd).

(Shows by means of diagrams the most important facts concerning the planets and their satellites.)

Film-strips

No. 98, *Great Astronomers*.

(The first 'star-gazers.' Ptolemy and other Greek thinkers. Astrology and astronomy. Copernicus. Galileo and the telescope. Tycho Brahe, Kepler, Newton, Halley, Herschel, and their contributions to astronomy.)

No. 99, *The Night Sky*.

(Diagrammatic representations of the form and position of the principal constellations and how to identify them.)

Picture Postcards, Photographs, and Lantern-slides

The Science Museum, South Kensington, London, S.W.7, contains collections illustrating optical instruments and astronomy, and picture postcards, photographs, and lantern-slides illustrating the exhibits in these

sections can be obtained from the Museum. Full particulars and lists can be obtained on application to the Director.

Models to show the Construction and Action of Telescopes

The plywood trough and cover illustrated in the last section on "The Microscope" can be used for assembling quickly for demonstration purposes the various forms of telescopes. Pupils see clearly the nature and position of the component lenses and stops, and when they are assembled they work. The four diagrams which follow



FIG. 131. DEMONSTRATION ASTRONOMICAL TELESCOPE

illustrate the types of lenses required and their relative positions. Actual focal lengths and distances between lenses are given as a guide, but any long-focus lenses will act as objectives and short-focus lenses as eyepieces. Suitable lenses can be obtained from the cheap stores or from any of the firms previously mentioned.

Methods of mounting the lenses in short lengths of ebonite tubing have also been described in the last section.

Fig. 131 illustrates the arrangement of lenses, in short lengths of ebonite tubing, for a demonstration astronomical telescope. The lenses are mounted in holes drilled in cylindrical pieces of wood or cork. *A* is a plano-convex lens 40 mm. in diameter and 115 mm.

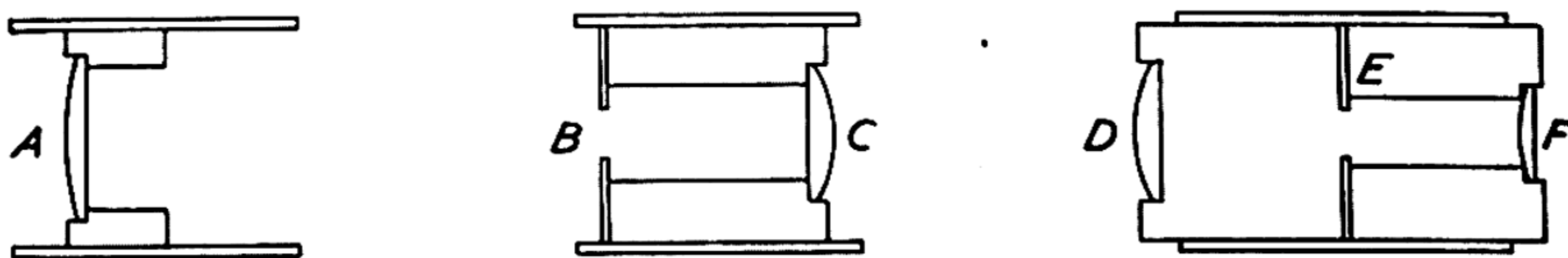


FIG. 132. DEMONSTRATION TERRESTRIAL TELESCOPE

focus, *B* is plano-convex 20 mm. in diameter and 30 mm. focus, and *C* is 15 mm. in diameter and 30 mm. focus. The stop *D* consists of a 10 mm.-diameter hole in a metal ring. The distance between *A* and *B* is about 110 mm., and between *B* and *C* 30 mm.

Fig. 132 illustrates the arrangement of lenses in a demonstration terrestrial telescope. *A* is a plano-convex lens about 40 mm. in diameter and 130 mm. focus, *B* is a stop made as before, and *C* is a plano-convex lens 20 mm. in diameter and 35 mm. focus. The

lens D should be exactly like C , E is another stop, and F is a plano-convex lens 15 mm. in diameter and 25 mm. focus. All surfaces of the cylindrical supports for the lenses and the stops should be painted dead black. The distance between A and B should be 130 mm., between B and C 25 mm., between C and D 70 mm., and between D and F 50 mm.

Fig. 133 illustrates the arrangement of lenses in a demonstration Galilean telescope. A is a plano-convex lens 40 mm. in diameter



FIG. 133. DEMONSTRATION GALILEAN TELESCOPE

and 130 mm. focus, B is a stop, and C is a double concave lens 20 mm. in diameter and 20 mm. focus. The distance between A and C should be about 80 mm. Opera glasses consist of a pair of Galilean telescopes.

Using the same lenses, A , D , and F , as are used to demonstrate the construction of a terrestrial telescope (Fig. 132), a demonstration prism telescope can be quickly assembled, as illustrated in Fig. 134.

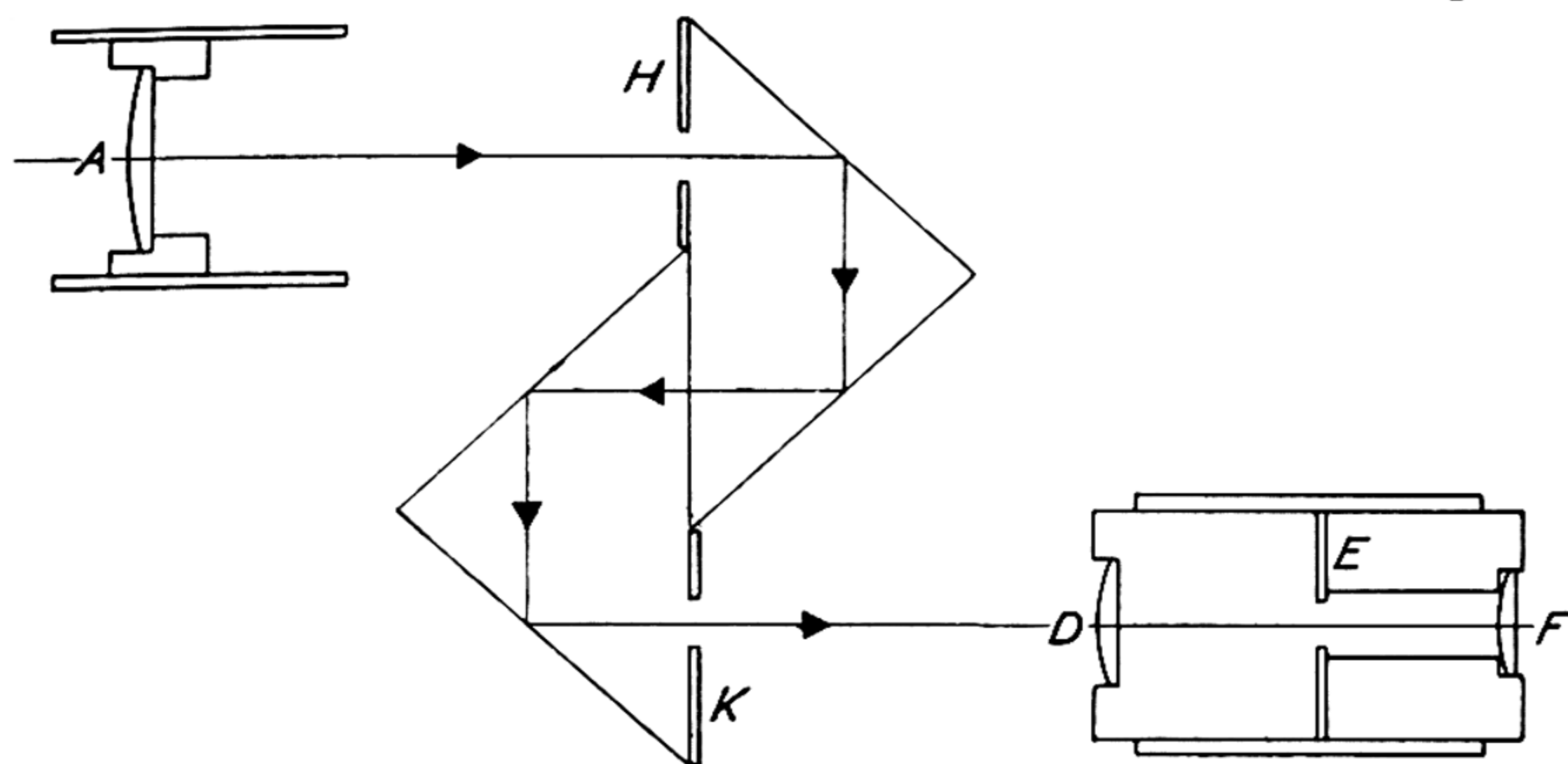


FIG. 134. DEMONSTRATION PRISM TELESCOPE

The pieces of ebonite tubing holding the lenses, and the glass prisms, should be placed on a horizontal board the surface of which has been painted dead black. It can be shown how this model produces the same results as the terrestrial telescope, how the erecting lens, C , can be dispensed with, and how the distance between eyepiece and

objective is very considerably reduced. The bases of the prisms should be painted with dead-white paint.

Drawing-pins in the horizontal board will prevent the pieces of tubing holding the lenses from rolling away. The right-angled prisms should have their upper surfaces about $1\frac{1}{2}$ in. above the surface of the board. *H* and *K* are pieces of sheet metal painted dead black on both sides, and having holes about 1 cm. in diameter in line with the optical axes of *A* and the combination *D* and *F* respectively. The horizontal board supporting this demonstration telescope should be raised up so that the eye can be placed near the lens *F*. Prism binoculars consist of a pair of such telescopes.

The action of the lenses and the paths of the light waves in the above telescopes can be shown by using the arrangement described and illustrated in the section on "The Microscope" and cylindrical instead of spherical lenses.

The above improvised telescopes lead to some discussion of the defects of lenses and methods of eliminating these defects. Methods of demonstrating the effects of spherical and chromatic aberration have already been described.

The World's Largest Telescopes

REFLECTORS

200-in.: Mount Wilson Observatory, near Pasadena, California.

This telescope would detect the light emitted by a candle 40,000 miles away. It was completed during 1940.

100-in.: Mount Wilson Observatory.

Full information about telescopes constructed by Sir Howard Grubb, Parsons and Co. can be obtained on application to their Optical Works, Walker Gate, Newcastle-on-Tyne.

REFRACTORS

40-in.: Yerkes Observatory of the University of Chicago, Williams Bay, Wisconsin.

36-in.: Lick Observatory, Mount Hamilton, California.

A good orrery is a very great help when teaching the elements of astronomy in connexion with the work on telescopes. The Bowyer Clockwork Orrery, obtainable from Baird and Tatlock, Ltd, 14-17 St Cross Street, Hatton Gardens, London, E.C.1, is excellent. The apparatus shows the following clearly, both separately and together:

- (1) The cause of day and night.
- (2) Varying length of days—sunrise and sunset.
- (3) The phases of the moon.
- (4) Eclipses.

- (5) The inclination of the earth's axis.
- (6) The parallelism of all its positions, and thus the succession of seasons.
- (7) The names of the months, with appropriate positions of the axis.
- (8) That the earth's distance from the sun varies.
- (9) The earth's orbit.

CHAPTER IV

ELECTRICITY IN THE SCIENCE ROOM. AQUARIA. A SCIENCE TIME CHART

Distribution of Electricity in the Science Room

QUITE often the first problem to be solved when work requiring electricity is contemplated in the science room is how to obtain electricity of various voltages to work the apparatus and models which will have to be used.

If the school is not supplied with electricity, this is no reason why work requiring electric current should not be attempted. Much of the work described in this book can be done with batteries, accumulators, and motor-car batteries. Most schools are now supplied with alternating current at 230 volts. There may be a few schools where a supply of direct current is available.

The model potentiometer here described, and illustrated in Fig. 135, can be used to step down the voltage of a direct- or alternating-current supply for working electrical apparatus requiring various voltages. This apparatus is ideal for use by the teacher for demonstration experiments, and should not be used by pupils.

The model consists of three uralite panels fitted into a wooden case. The front panel serves as the distribution panel, the inner one is the potentiometer panel, and the back panel prevents anyone from touching the extreme ends of the potentiometer wire, where the difference in voltage is 230. Scrap pieces of uralite which have been broken from large sheets can usually be obtained from builders' merchants for a few pence. To cut this uralite along a desired line it should be placed on a table and a deep groove made along the line by running a pointed steel instrument along the edge of a steel ruler. When the groove is about $\frac{1}{16}$ in. deep the uralite can be broken along the line by placing the uralite with the groove in line with the edge of a table, groove uppermost, and pressing down on the piece overlapping the edge of the table. Holes can be drilled in uralite with ordinary steel drills.

Holes should be bored in the bottom of the wooden case. The lid should be hinged, so that it may be opened when the apparatus is in use, and to allow connexions to be made to the wire on the inner panel, which should be placed about one inch from the back panel. The wire on the inner uralite panel consists of three lengths of spiral curtain wire. Pull out the wire until adjacent turns are not touching

each other, and then thread it through holes drilled in the uralite, as indicated in the sketch. Connexions are made to this wire, from the terminals on the distribution panel, by means of crocodile clips. If the total length of wire is twenty feet and the voltage of the mains

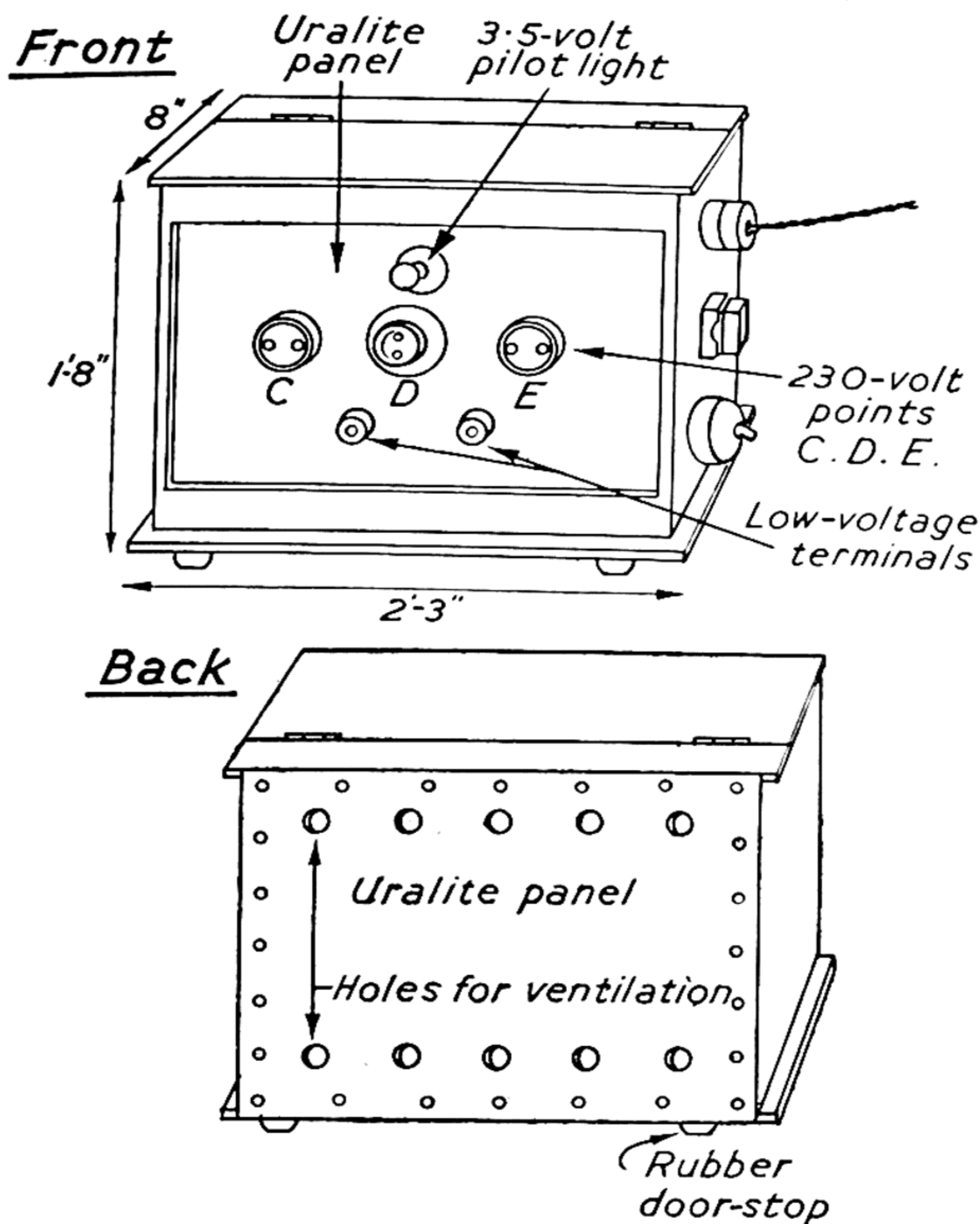


FIG. 135(a). MODEL POTENTIOMETER

230, half the length of wire will give 115 volts, a quarter of the wire 57.5 volts, and so on, any voltage from 1 to 230 volts being obtainable.

A cheap, safe, and effective method of distributing low-voltage alternating current electricity to all the tables and benches in the science room is shown in Fig. 136.

A number of mains points, A, B, C, D, and E, should be available. They may be wall-plugs and sockets, or leads may be taken from lamp sockets by using two-way adaptors. Wall-plugs and sockets

preferably should be of the three-pin interlocking type; these prevent the plug from being pulled out when the switch is on. Moreover, while the plug is out the switch cannot be turned on. *F, G, H, I, J,*

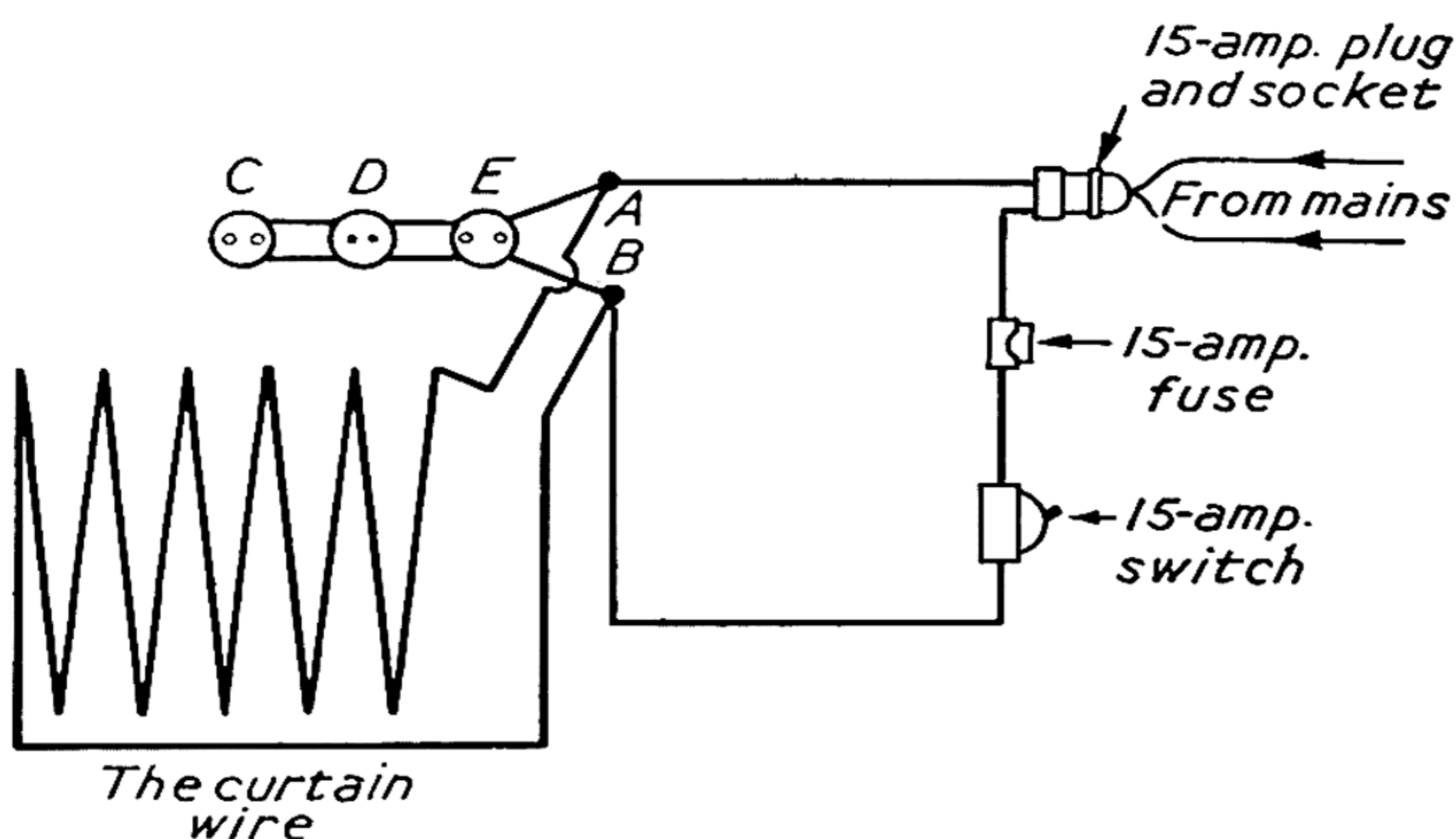
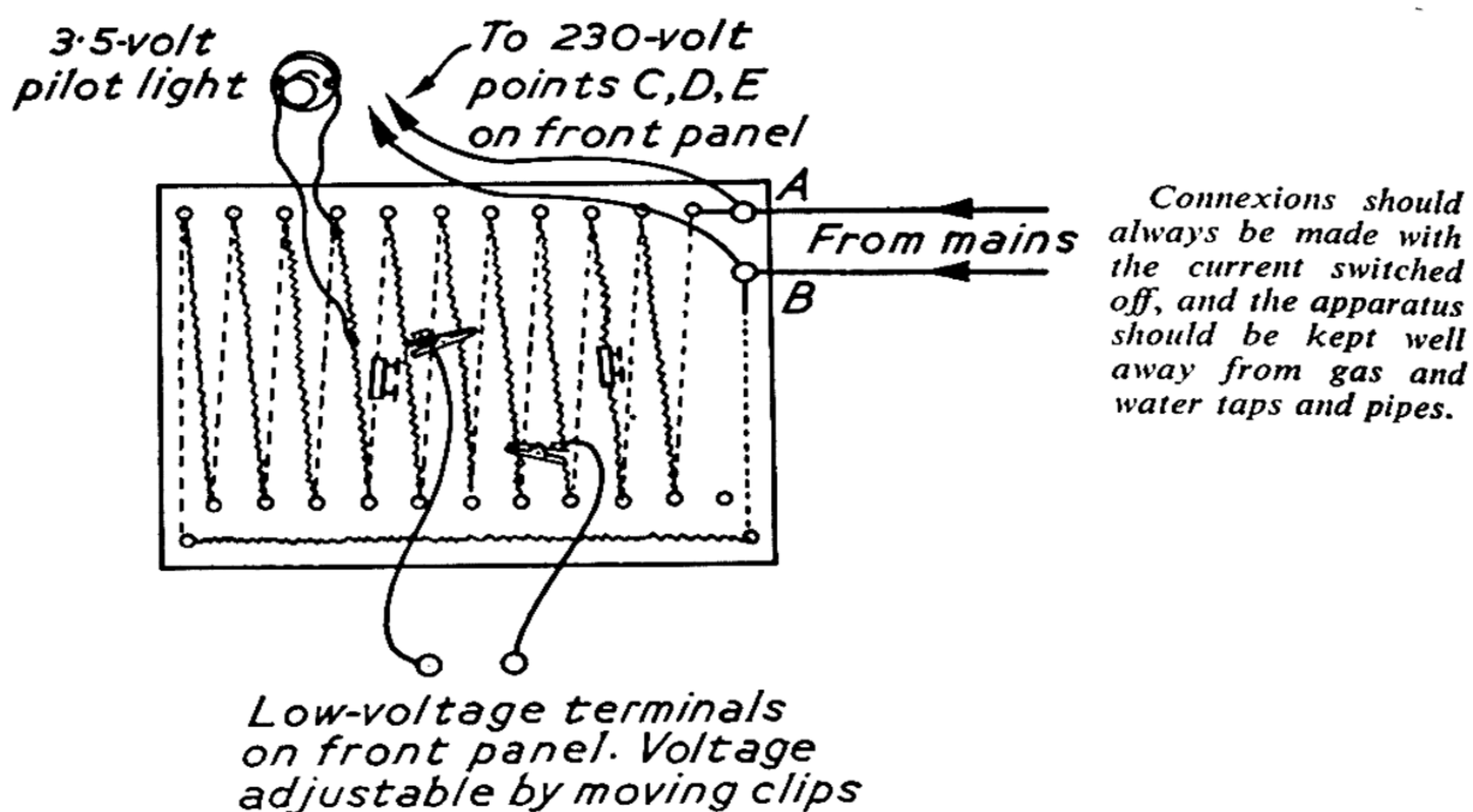


FIG. 135(b). MODEL POTENTIOMETER

K, L, M, N, O, and *P* are distribution boards, one for each pupil's table and one for the teacher's table. The boards are pieces of oak 14 in. by 7 in. In the centre of each board is a surface switch socket and plug of the three-pin interlocking type. The switch socket of *F* is wired to the plug *A* by a length of 5-amp. flex. The switch sockets

of *G*, *H*, and *I* are wired in parallel to the plug of *B*, those of *J*, *K*, and *L* to the plug of *C*, those of *M*, *N*, and *O* to the plug of *D*, and that of *P* to the plug of *E*. The diagram shows the method of wiring.

The flex from *B* to *I*, from *C* to *L*, from *D* to *O*, and from *E* to *P* should be fixed above the pupils' heads, and the flex from one switch socket to another should be made long enough to be taken under the

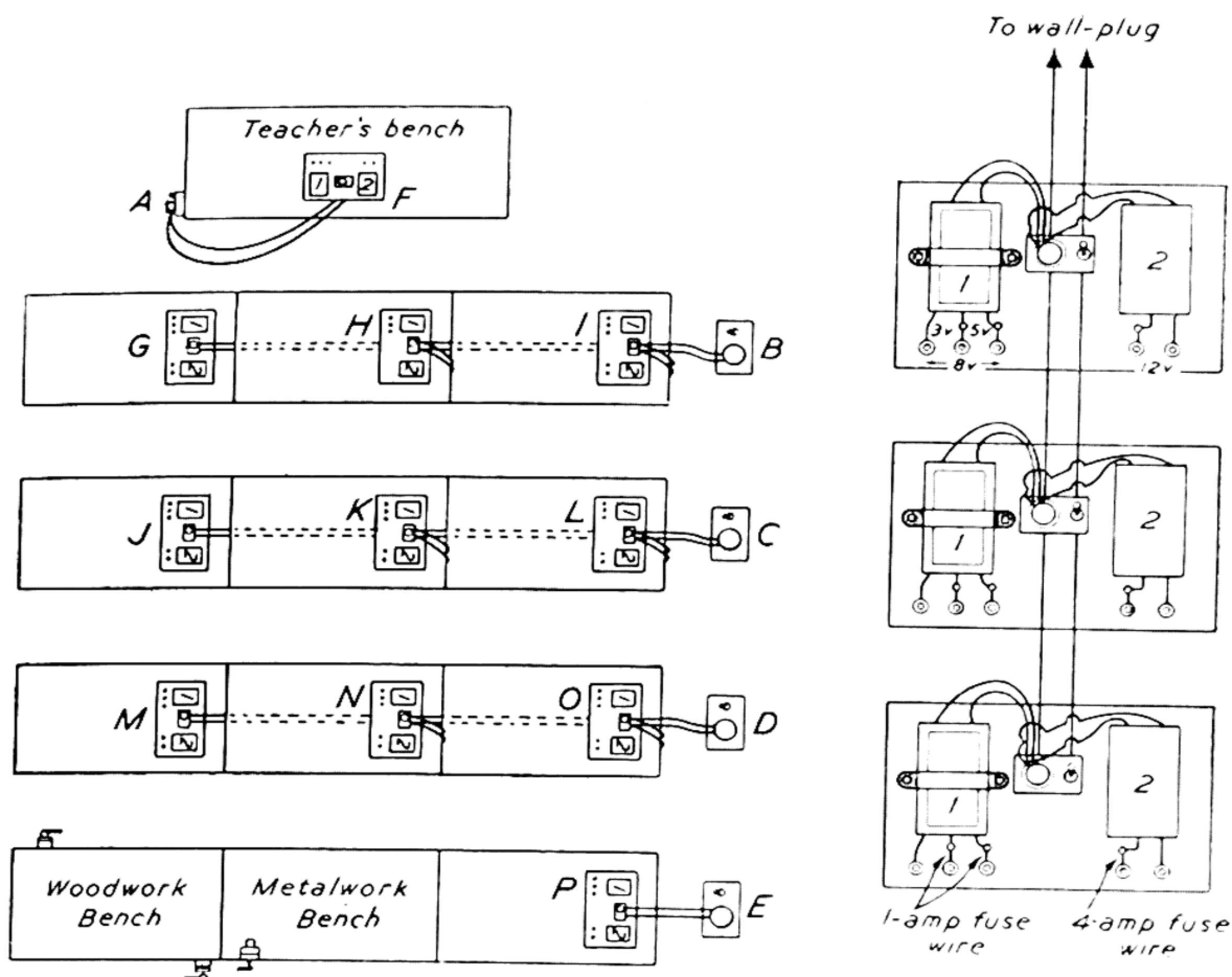


FIG. 136. DISTRIBUTING LOW-VOLTAGE ALTERNATING CURRENT

tables, as indicated by the dotted lines in the illustration. The process of wiring is simplified, of course, if there are electric points in wells in the floor. In science rooms where electricity points are already fitted they are usually attached to the walls above the side benches.

The apparatus numbered 1 to each distribution board is a Bakelite bell transformer. The input voltages are 200–250, and the output 3, 5, and 8 volts at a maximum of about 1 amp. The two input terminals are wired to the plug of the switch in the board, and the three output terminals are wired to three brass terminals fixed to the board near the transformer. Care must be taken to see that the input

terminals of the transformer are well insulated, and the transformer cover should be held down on to the baseboard by a brass strip, as indicated in the illustration.

The apparatus numbered 2 on each board is a transformer, the input voltages of which are 200–250 volts, and the output voltage 12 volts at a maximum of about 4 amps. Such transformers can often be obtained from Electradix, 218 Upper Thames Street, London, E.C.4. The input terminals of these transformers are also

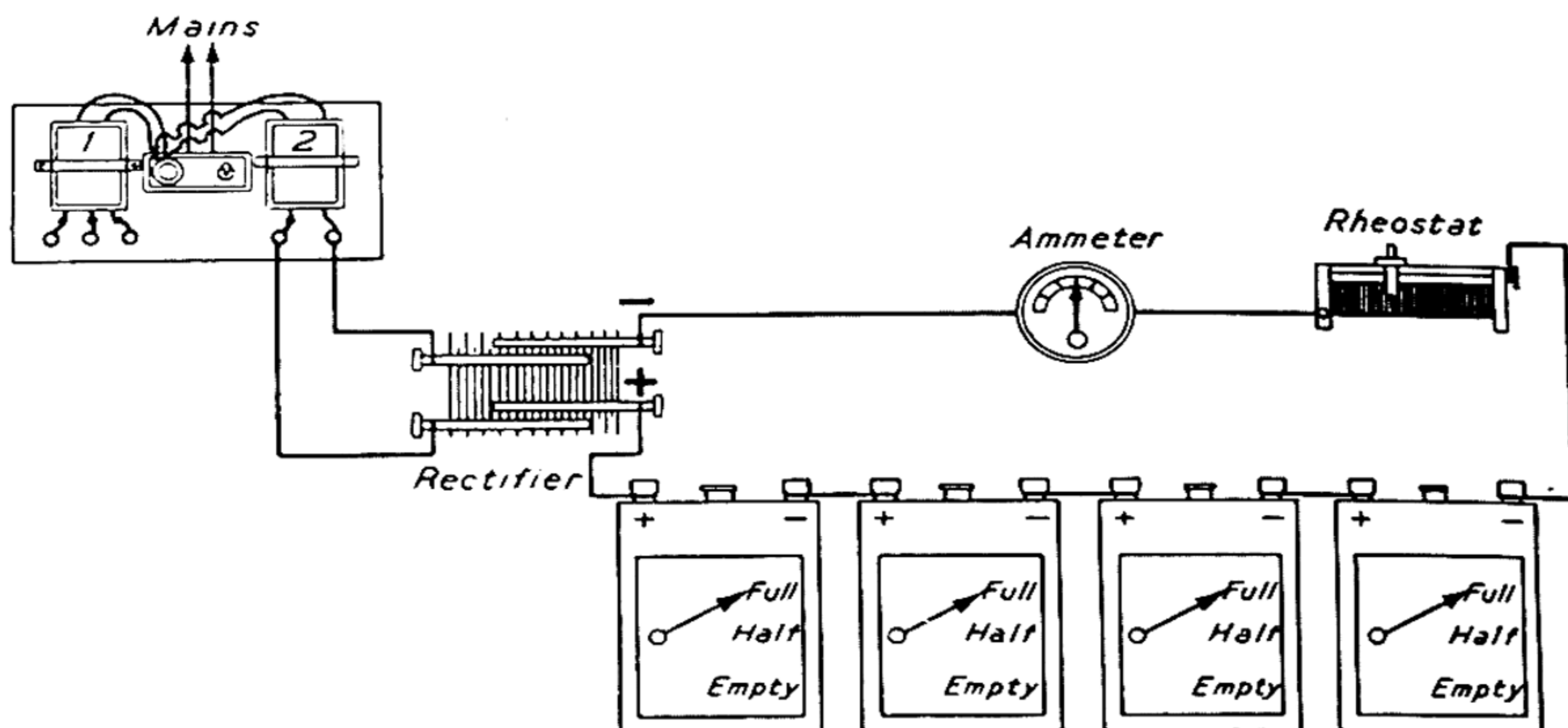


FIG. 137. ACCUMULATOR CHARGING

wired to the plug of the switch on the board, and the output terminals to two brass terminals placed near the transformer. A wooden box or some other protection should be fixed over these transformers to prevent pupils from touching the input terminals. A three-wire system for the mains supply is advisable if three-pin plugs and sockets are available in the science room with the earth wire connected to one side of the transformed secondary coils. Mains voltage must not be used on benches where they may come near gas or water pipes or taps.

There is little danger of pupils receiving an electric shock if care is taken to cover the input terminals of the transformers, and the apparatus can be protected from short-circuiting by including a length of fuse wire between the brass terminals and the transformer terminals as indicated in the illustration.

These distribution boards will be quite adequate for supplying current for most of the models and experiments described in this book and *Everyday Science Topics*, Books I, II, and III.

For direct-current work in a science room supplied with alternating

current the cheapest and most convenient method is to have a number of accumulators of the Exide Indicator D.M.G.-C. type, and one Westinghouse-type A6 rectifier, so that they can be charged from the 12-volt terminals on the distribution board (Fig. 137).

Full information about the rectifier can be obtained from the Westinghouse Brake and Saxby Signal Company, Ltd, 82 York Way, King's Cross, London, N.1.

If four accumulators are charged at once the current will be kept just below 2 amp., the correct charging rate of current. The indicators tell at a glance the state of the accumulators. These should not be allowed to fall below "Half," and when they point to "Full" charging should stop. By means of the rheostat the charging rate can be cut down when the accumulators begin to gas freely.

In a laboratory supplied with 230-250 volts A.C., direct current can be obtained for charging accumulators or for experimental work by using car-battery chargers. These cost from £4-£5 at the present time.

Aerating Aquaria

In a laboratory with twenty or thirty small aquaria it is sometimes difficult to preserve in each aquarium the balance between plant and animal life which is so necessary for the comfort of the inmates. A little aeration daily is usually necessary.

There are many aerators on the market, but most of them are designed for aerating only one aquarium at a time. Many of these aerators carry water into the aquarium in addition to air, thus disturbing the water-level, so that supervision is necessary. There are more satisfactory motor-driven aerators, but these are usually very expensive.

An Aerator from a Model Steam-engine

The model aerator illustrated in Fig. 138 will force air through a dozen or more aquaria simultaneously, and no supervision is necessary. The aerator may be made from apparatus which most science teachers already possess. A small 6-12 volt electric motor and a small model oscillating cylinder steam-engine are necessary. The electric motor from an old motor-car hooter may be used. Such hooters can be obtained from garages for a few shillings. A child's toy steam-engine will serve as the air pump.

The engine and motor are mounted on a baseboard and connected by a Meccano chain passing round Meccano sprocket-wheels soldered to the pulley or axle of the electric motor and the fly-wheel of the steam-engine.

A steam-engine of the Stuart Turner "S.T." type ($\frac{7}{16}$ in. bore,

$\frac{7}{16}$ in. stroke) is ideal. (Obtainable from Stuart Turner, Ltd, Henley-on-Thames.)

Rubber tubing of about 6 mm. bore leads round the room from the steam-engine outlet, as illustrated. Connexions are made from

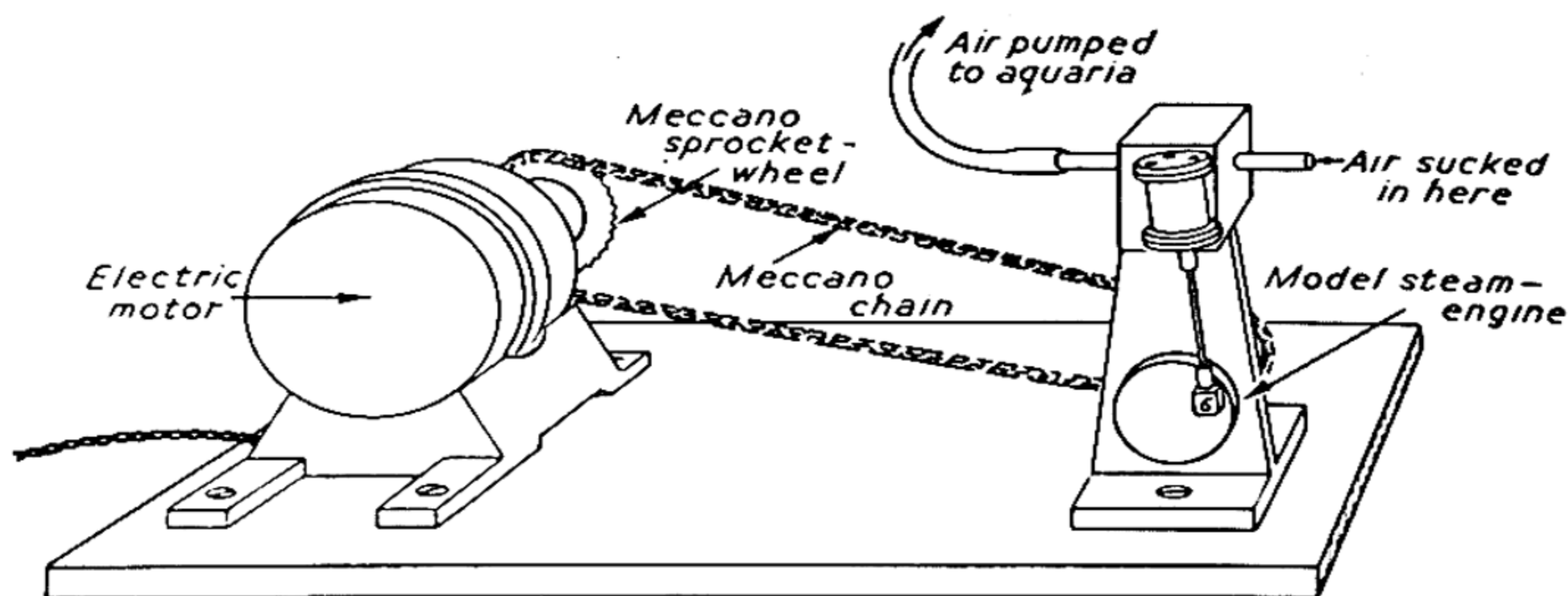


FIG. 138. AERATOR

this tubing to the aquaria by means of glass T-tubes. Clips are placed on the rubber tubes which lead into the aquaria, so that the air can be cut off from any aquaria without interfering with the air-supply to the others. Narrow-bore glass tubes actually lead the air into the aquaria, and these must be immersed to the same

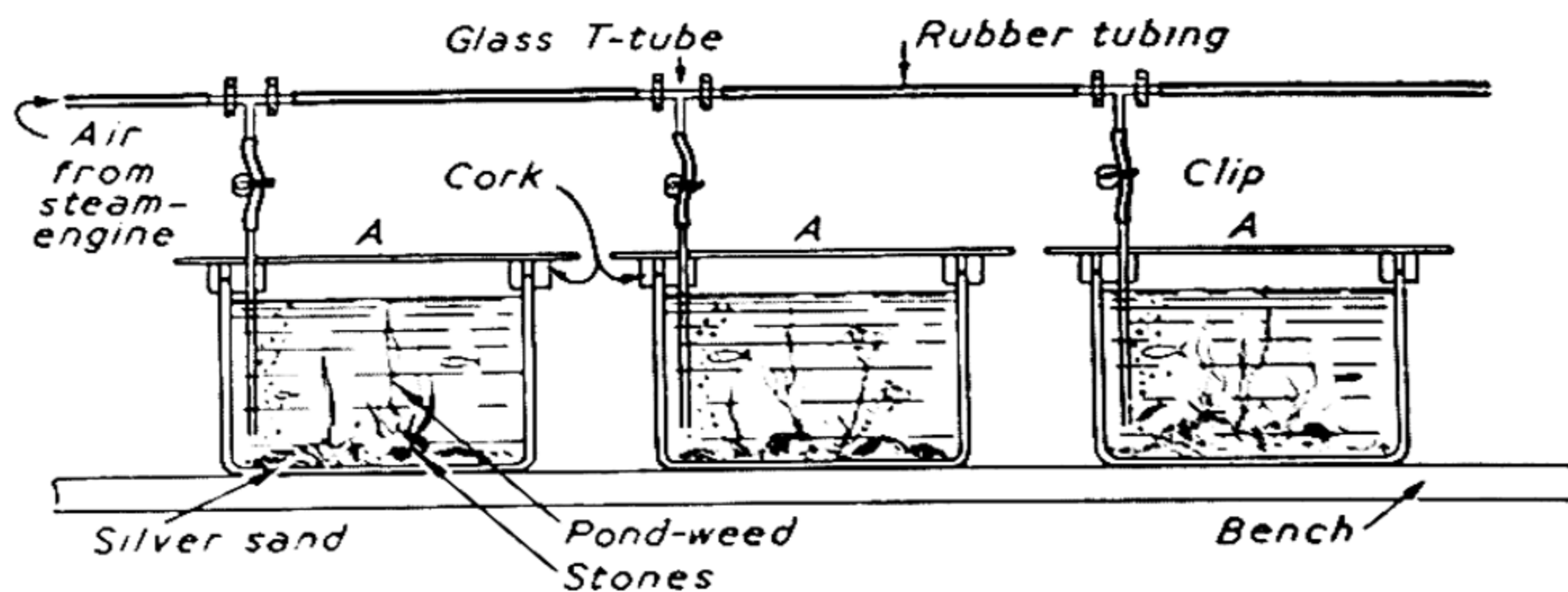


FIG. 139. AERATING AQUARIA

depth in each aquarium, otherwise the air will escape from some tubes and not from others.

The motor and engine can be placed on a shelf out of the way, and, if all moving parts are lubricated from time to time, the apparatus will be almost silent during operation.

The parts marked *A* (Fig. 139) are pieces of glass supported about an inch above the upper edges of the aquaria to allow for air circulation and to prevent dust falling on to the surface of the water. Pieces are cut out of the glass to allow the aerator inlets to pass through. The tanks should be covered with dark paper so that one side only

is left for observation, the light entering the tank from above, from an electric lamp if necessary.

Another Home-made Aerator

This automatic aerator, made from articles which are all cheap and easily obtained, has proved highly satisfactory in keeping creatures alive and comfortable for long periods in small aquaria in the science room.

It will pump air, freed from carbon dioxide if required, into an aquarium at a rate which can be adjusted. The aerator can be left working night and day if necessary without any attention. The water in the aquaria need be changed only when it becomes fouled with excreta. The aerator delivery pipe can be left in each aquarium for about two or three hours at a time.

Dimensions are stated on the diagram, and the length of tubes must be exactly as shown. The narrow tubing should be 5 or 6 mm. bore, and the siphon tube at least 8 mm. bore. *A* is a well-fitting bung; a rubber bung is best, but a cork from a pickle jar will do if it is sealed in with paraffin-wax or sealing-wax. If a rubber bung is used, extra holes can be bored with a twist drill. The drill should be twice the diameter of the hole required. After drilling the holes can be cleaned out with a red-hot iron rod.

The rate of action of the aerator can be controlled by adjusting the rate of influx of water. As the milk bottle is filling up with water air is forced into the aquarium. When the bottle is full of water the siphon tube quickly empties this into the sink, and air is sucked into the bottle through the test-tube. If the water siphons out prematurely or does not siphon out quickly enough, this can be remedied by altering the rate of influx of water from the tap. A very slender stream of water will work the aerator.

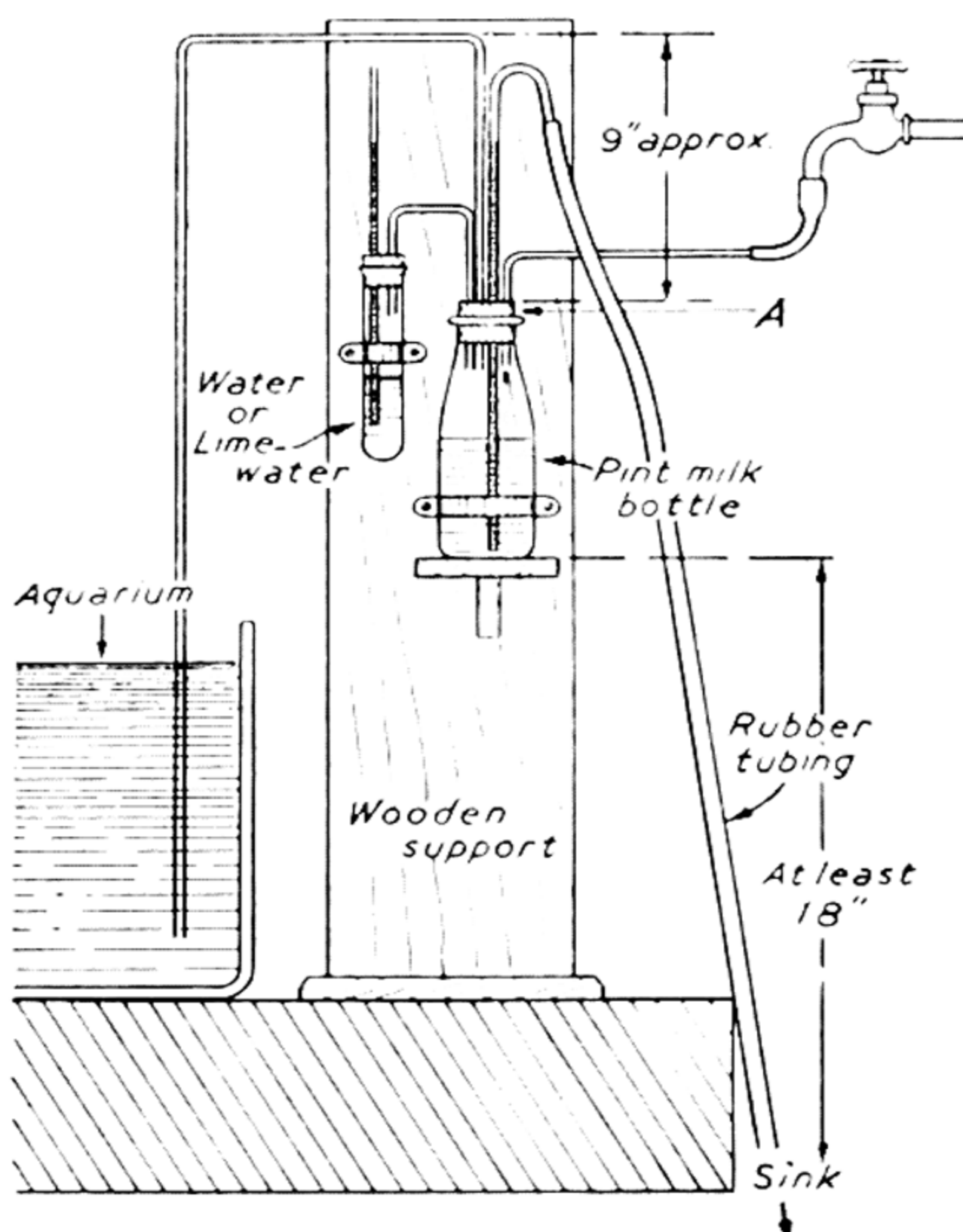


FIG. 140. AUTOMATIC AERATOR

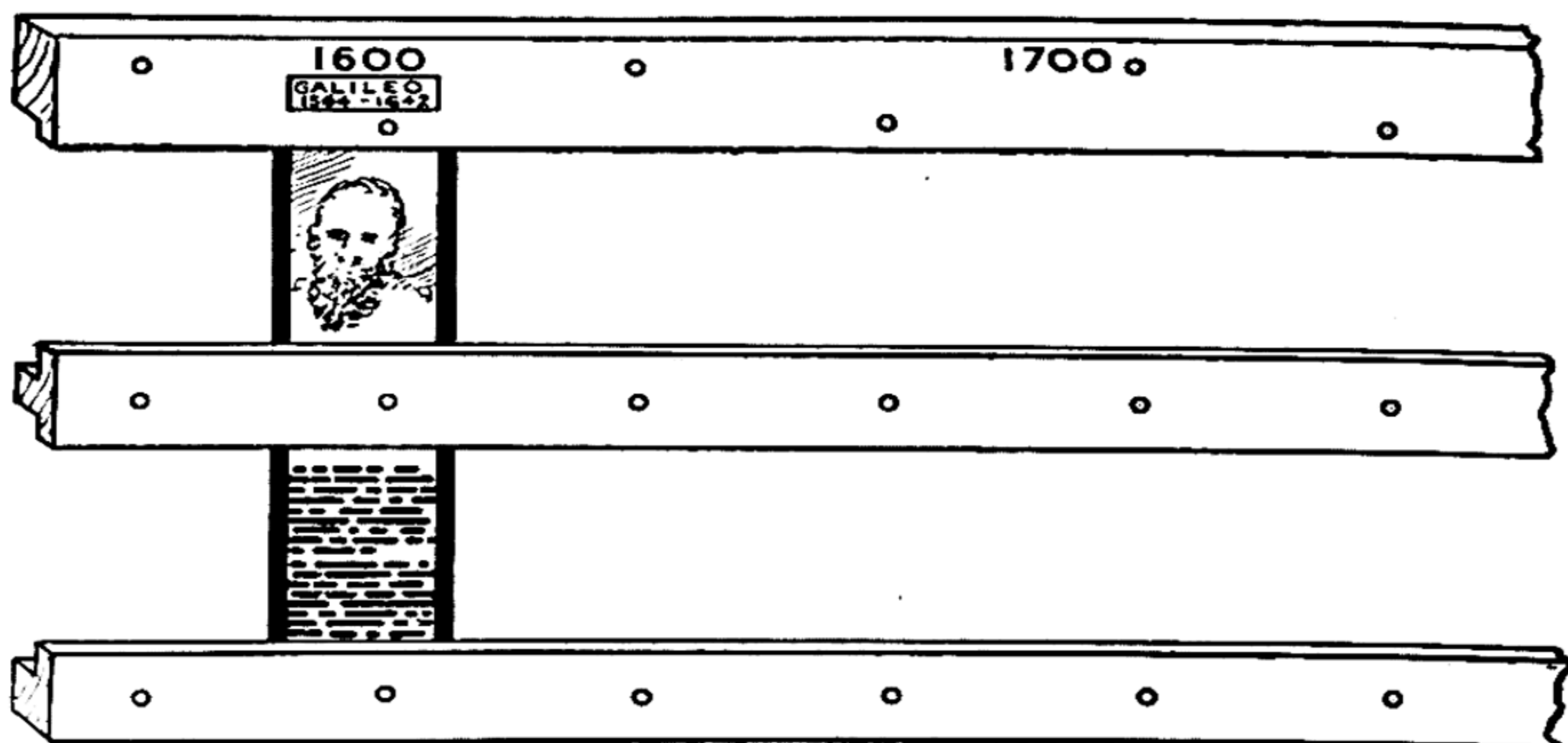


FIG. 141. TIME CHART

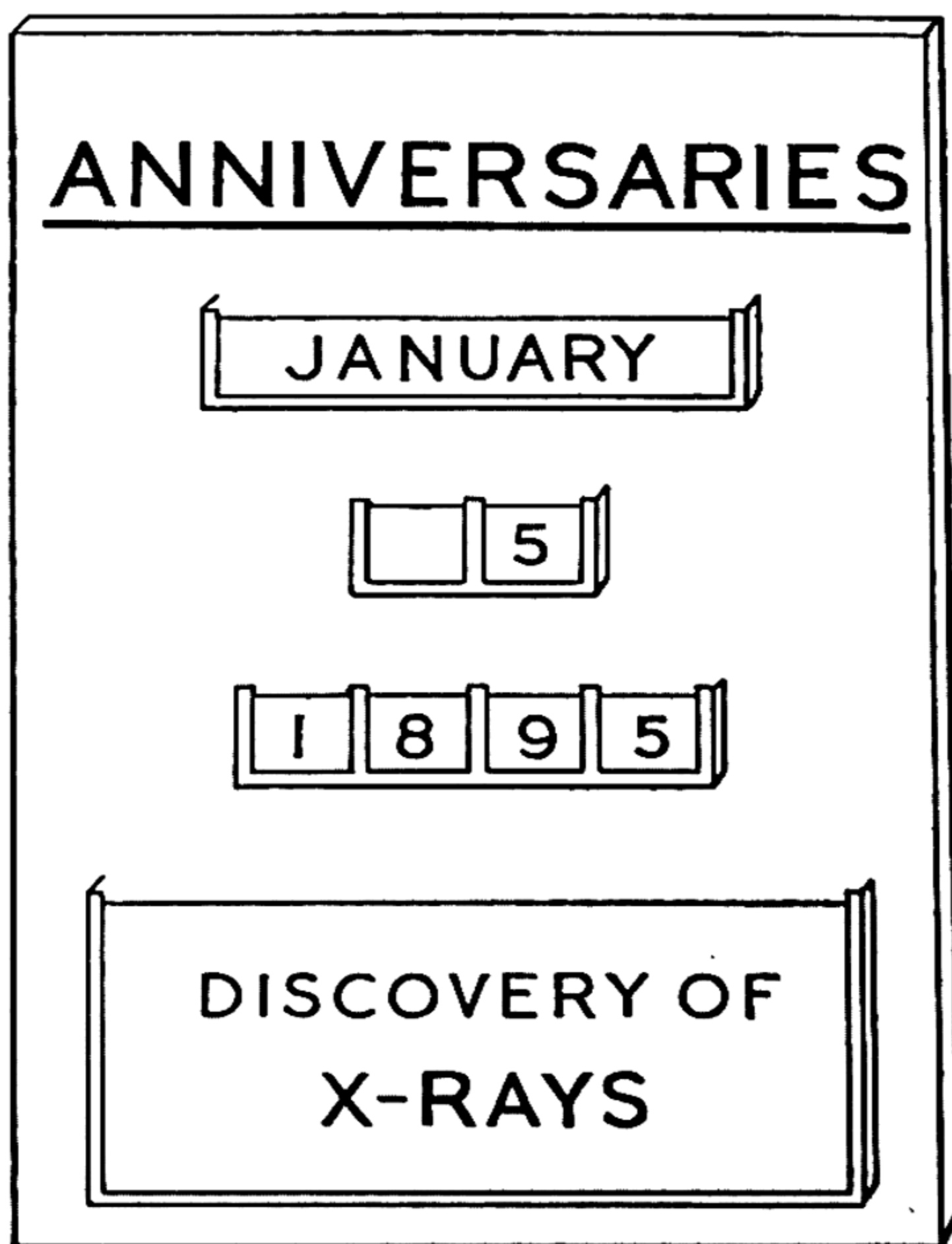


FIG. 142. ANNIVERSARIES BOARD

A Science Time Chart

As work proceeds on the various topics the names of famous men of science and important events in the world of science will be mentioned from day to day. As these great names and events are referred to it is an excellent plan to build up a permanent record and reminder. The best way of doing this is to build up a time chart or gallery of famous men round the walls of the science room, or in a corridor leading to the room.

Fig. 141 shows a method of arranging this.

The name and dates should be printed on a piece of white cardboard, which can be fastened to the upper board with drawing-pins. The photographs or prints are taken from old text-books, or obtained from science museums. They are placed on a piece of cardboard, a piece of glass is placed over the print, and the edges are bound together with *passe-partout*. The neatly printed summary of the scientists' work for mankind is treated in the same way. These are made of such a size that they can be easily slipped into the rack. Suitable photographs can be obtained from books and from the Science Museum, South Kensington.

Important scientific events should be recorded along with other important events on a daily anniversaries board hung in the school's assembly hall. Helpful calendars of such events are given in most encyclopædias. There is a good one in the Waverley Book Company's *New Book of Knowledge*, vol. x (1947).

Details of the events, names of the months, and numbers for the dates are printed on pieces of white card, which are slipped into slots.

CHAPTER V

OPTICAL AIDS IN THE SCIENCE ROOM

Types of Optical Aids

OPTICAL aids include all those devices by means of which systems of lenses project images of epi- or dia-positives (epi-positives—opaque pictures and objects; dia-positives—films and slides).

The most important are:

(1) Diascopic apparatus:

- (a) Standard ($3\frac{1}{4}$ in. by $3\frac{1}{4}$ in.) lantern-slide projectors.
- (b) Film-strip projectors.
- (c) Micro-projectors.
- (d) 16 mm. sound and silent cine-projectors.

(2) Episcopes for the projection of opaque materials, such as the picture postcard or book.

(3) Combinations of the above, such as the epi-dia-scope.

At least one good film-strip projector, an episcopes, and a 16 mm. cine-projector are essential for use in the science room. The use of the standard ($3\frac{1}{4}$ in. by $3\frac{1}{4}$ in.) lantern-slide projector, which was for a long time the only optical aid, is now confined almost entirely to the science room. Micro-projectors for microscope slides are for the use of the science specialist, and the epidiascope is merely an episcopes plus the standard lantern-slide projector.

The Purpose of the Optical Aids

(1) *Film-strip Projector*

The best type to have is that for projecting film-strips 35 mm. wide, with pictures 18 mm. by 24 mm. or 24 mm. by 36 mm., and having a double line of sprocket holes, as there is now quite a plentiful supply of this type of film-strip and they are the most convenient to use. These film-strips offer a very compact and economical means of conveying static pictorial information, for sixteen pictures can be carried on a single foot of film, and several feet of film, the equivalent of perhaps a hundred or more lantern-slides, can be rolled up and carried in the waistcoat pocket. Hundreds of film-strips can be stored in a very small space, and they cost about 3d. per picture to purchase. Film-strips can be made up from a

teacher's own collection of pictures, photographs, or drawings, at a very small cost.

With a good film-strip projector only a partial blackout of the room is necessary, including that part near the screen.

(2) *Episcope*

An episcope projects the light which is reflected from the surface of opaque pictures and objects, and possesses the very great advantage that the teacher can project on to the screen in its original colours any printed picture, drawing, the page of a book, a map, and even solid objects. The light output is, however, feeble compared with diasopic apparatus, and a more complete blackout of the room is therefore necessary when it is being used.

(3) *16 mm. Cine-projector*

Substandard 16 mm. film, printed on non-inflammable stock, has become standardized for school use. Silent 16 mm. film has sprocket holes on both edges; 16 mm. sound film has sprocket holes on one edge and the sound track on the other.

For most classroom purposes silent films are best. There are, however, many good sound films which can be used to give highly effective lessons.

Films for use in the science room fall broadly into two classes.

(a) FOREGROUND, OR CLASSROOM, FILMS

These are for incorporation into the ordinary routine, and should stand on the same level as an experiment. They are part of the lesson, and convey ideas or information which cannot be imparted in any other way. Films such as these can be used by the teacher to show phenomena which necessarily involve motion or which are of so unusual a nature that it is difficult to present them in any other way. They form a sort of mechanical blackboard.

These films must never replace work that could be done by the teacher. Simple experiments which could be done as demonstrations should not be shown on the screen. Diagrams which can be drawn on the blackboard need not be shown by film. Moving pictures are never better than the things themselves, but they are more effective than the spoken or printed word for conveying ideas or information. Films widen the scope of the teacher, they do not replace him, nor should they encourage him to laziness.

Cyclic films fall into the foreground class. These consist of endless loops of film showing a moving diagram of any process which repeats itself at regular intervals—*e.g.*, the working of a dynamo or

steam-engine. Such films can be passed through the projector as often as is necessary to drive home the explanation.

For most classroom purposes films should be silent, as they lend themselves more readily to the teaching technique which experience has shown to be most effective, and the pupils' attention should not be diverted from the explanation itself to the means employed to explain.

Foreground films should be clear, lucid, simple, and logical, and not confused by noisy accompaniments. They should take not more than about ten minutes to show. The school lesson is too short to have a longer period of projection, and a film which lasts longer will exhibit more facts than a child can master in an hour.

(b) BACKGROUND FILMS

The use of films in classrooms during ordinary lessons does not exhaust their possible utility. They should also be used to widen children's ideas, or to interest them in aspects of life which are not touched on in the ordinary curriculum—in short, to broaden the outlook of the children.

These functions are perhaps best carried out by good sound films which aid effective presentation and secure lifelike production. The greater realism probably results in stronger and more lasting impressions on the minds of the pupils. Children now expect a background of sound, and, in consequence, may become dissatisfied and lose interest when only silent films are used.

Therefore I would say generally use silent films for the classroom and sound films for general background work in the hall or science lecture room. The ideal arrangement would be to have in each school two or three 16 mm. silent projectors for classroom use and one 16 mm. sound projector. The next best thing would be to have one combined sound and silent projector, but a 16 mm. silent projector is really the first essential instrument, since this will be the machine most often used in ordinary teaching.

How the Projector works

The following diagrams are intended to illustrate broadly the principle underlying the projectors, and do not claim to be optically accurate in every detail.

(1) THE FILM-STRIP PROJECTOR

S is a powerful electric lamp (may be up to 250 watts) enclosed in a light-tight but well-ventilated box. *L* is the condenser, so placed that the light which falls on to it from *S*, and is reflected on

to it by the stainless-steel concave mirror M , after passing through L converges on to the diapositive D (the film-strip picture). O is the objective, or projection, lens, so placed that the whole of the converging beam passing from L may be taken up. O is moved backward and forward until a clearly defined image is focused on the screen, R . The image is always laterally and vertically inverted, and magnified in the ratio $\frac{RO}{OD}$.

It is obvious that the greater the distance RO , the larger will be the picture on the screen, but when enlarging the picture it is also

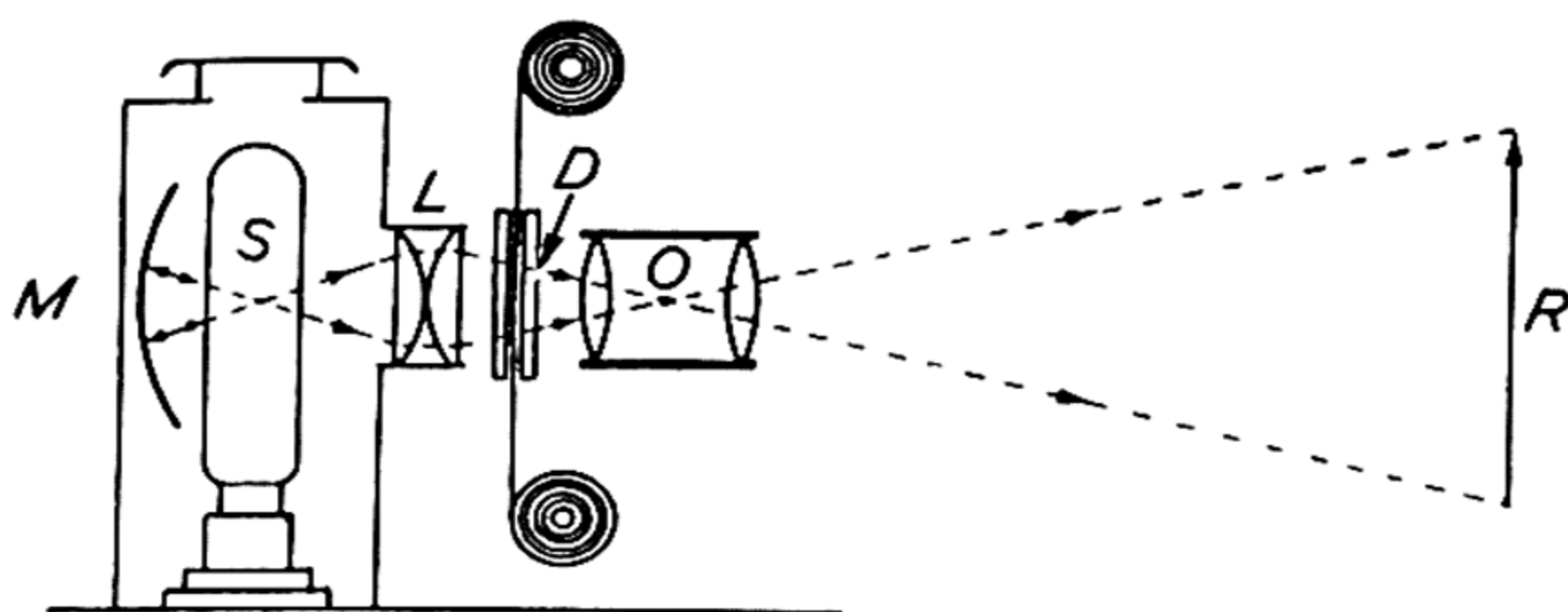


FIG. 143. FILM-STRIP PROJECTOR

important to bear in mind that a constant illuminating power is spread over a larger area and the intensity of illumination on the screen is diminished.

I believe that no advantage is gained for classroom purposes in enlarging the image on the screen beyond about 40 in. $\times$ 30 in. A larger screen (7 ft. 6 in. $\times$ 5 ft. 6 in.) is necessary for a school hall accommodating about 300 pupils, and a more powerful illuminant must then be used.

(2) THE EPISCOPE

S is a powerful source of light—usually an electric projection lamp or lamps of 500–1000 watts. On account of the intense heat from such lamps, electric cooling fans are incorporated in the bodies of some episcopes. To protect pictures from the heat they are often placed under a heat-resisting glass plate, P .

L is a condensing lens, so placed that it helps to concentrate the light on to the picture, A , placed on the platform B . After converging towards the picture the light is reflected there, and again at the mirror M , which directs the light towards the objective lenses, O , which throw an image of the picture on to the screen. The mirror M inverts the picture. So as to catch the maximum amount of light from the picture the aperture of the objective, O , is usually fairly large. The

platform *B* will usually take pictures or objects up to about 6 in. $\times$ 6 in. If it is desired to project larger pictures or maps, the episcopes can be lifted from its undercarriage, quickly fitted with special castors, and moved about over maps or pictures of unlimited area.

In the episcopes much light is lost by reflection and by absorption at the picture. This results in considerably reduced illumination of

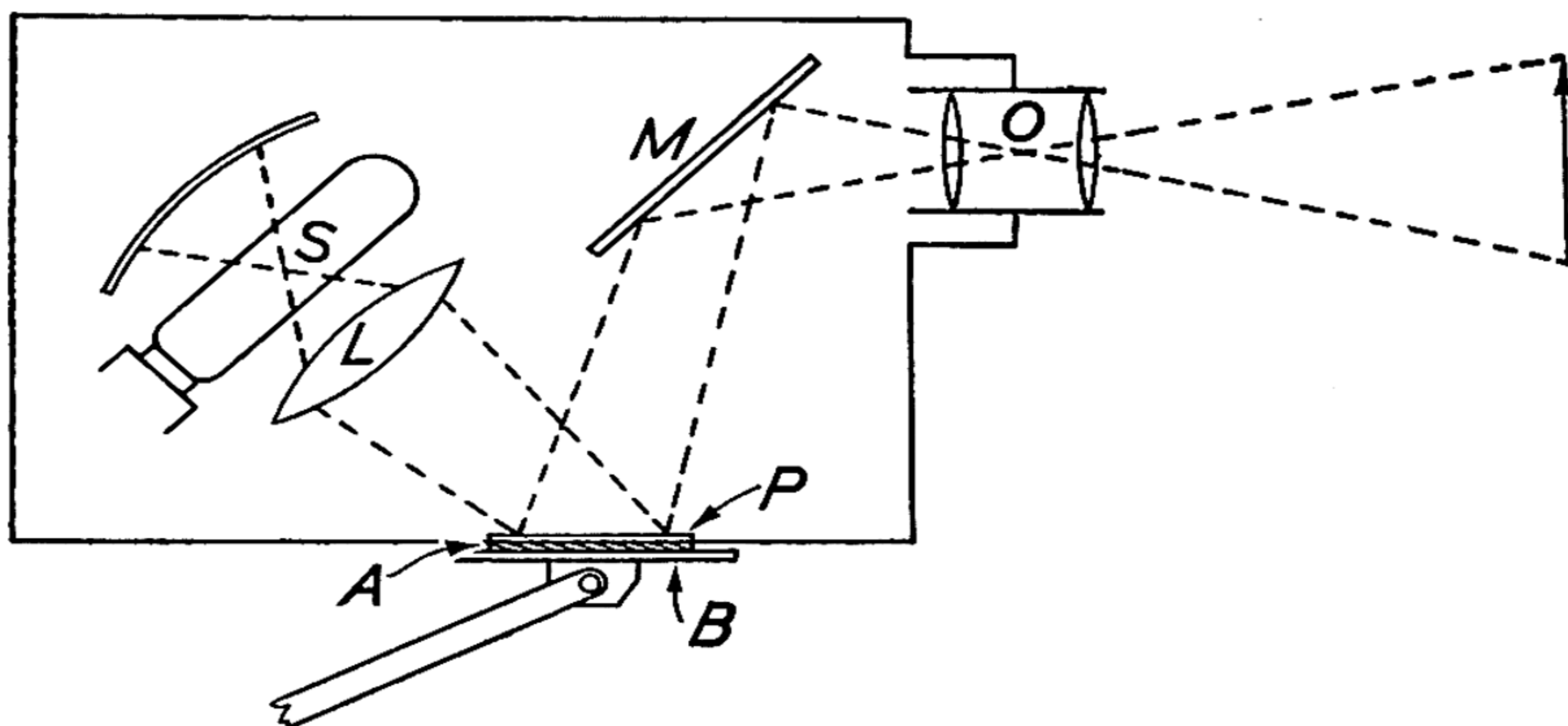


FIG. 144. EPISCOPES

the image on the screen; a good blackout and much more care in projection is therefore necessary.

(3) 16 MM. CINE-PROJECTORS

The optical arrangements in the silent projector are similar to those already described for the film-strip projector. Fig. 145 illustrates the principal parts of a combined silent and sound projector.

Modern projectors have been so simplified that it is not essential to understand very fully the mechanism they employ. Efficient use is, of course, facilitated by some understanding of the principles involved. An instruction book on the special operating methods for each type of projector is usually included with the projector at the time of purchase.

The Intermittent. Film projectors give an illusion of continuous motion by throwing on to the screen a rapid succession of still pictures. Sixteen times (or, for sound, twenty-four times) a second a fresh picture is thrown on to the screen, held stationary there, and whisked away again, after which a new picture is presented to follow on from the last. This is done by a series of rapid snatches

at the film by the "intermittent," or "pull down," and is shown in the diagram as a claw engaging with the film at the bottom of the gate. Different types of projectors have different types of intermittent mechanisms. Much time has been spent on perfecting these to avoid damage to films.

It is important to notice here in passing the different speeds at which sound and silent films must be run through a projector. This

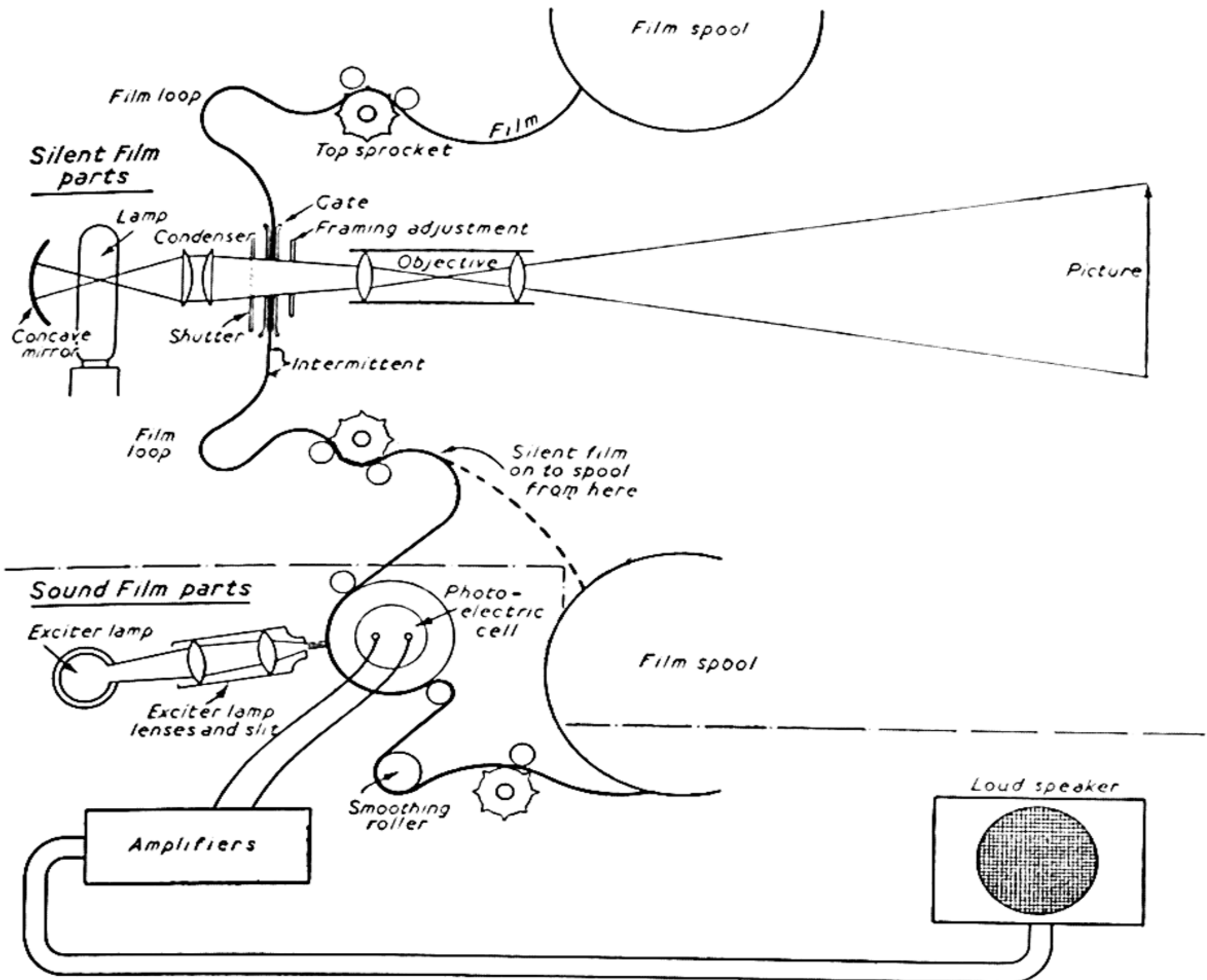


FIG. 145. COMBINED SILENT AND SOUND CINE-PROJECTOR

is usually controlled by means of a simple switch in the combined sound and silent projector.

The Lamp. May be a 300–750-watt lamp. These lamps become intensely hot in use. To reduce the local heating effect of the lamp it is usually cooled by an electric fan blowing a current of air over it while it is in use. The lamps have a burning life of approximately 30 hours, and they should be switched off whenever they are not required. A spare lamp should always be available, and care should be taken in removing a burnt-out lamp, or the fingers may be scorched.

The Shutter. This prevents the movement of the film from appearing on the screen while one picture is being substituted for another. It interrupts the light and darkens the screen for an instant. Special shutters have been designed to eliminate flicker.

The Gate. This holds the film just firmly enough to prevent its slipping in its downward course, but not too firmly, or it would strain the intermittent and damage the film. Loops of film are always left above and below the gate, which is usually made of stainless steel and must be kept absolutely clean and free from grit or dust particles.

The Objective. This produces an enlarged and inverted image of the film on the screen. For good, clear definition the lenses (which are usually achromatic combinations) must be accurately ground to a millionth of an inch. They must be kept clean, and, as they are made of relatively soft glass, care must be taken not to scratch them, for such scratches would appear as lines on the screen during projection. Special lens tissue can be obtained for cleaning. The focal length of the objective in any projector determines the size of the screen picture at a given distance from the screen. The table below gives data for 16 mm. cine-projectors.

FOCAL LENGTH OF OBJECTIVE IN INCHES	DISTANCE IN FEET FROM SCREEN						
	10	20	32	40	50	75	100
	WIDTH OF PICTURE						
	ft. in. 3 9	ft. in. 7 6	ft. in. 11 11	ft. in. —	ft. in. —	ft. in. —	ft. in. —
1							
2	1 10	3 9	6 0	7 5	9 4	—	—
3	1 3	2 6	4 0	5 0	6 3	9 4	—
4	—	1 10	3 0	3 9	4 8	7 0	9 4

SOUND-FILM PARTS

Light from the exciter lamp is concentrated by a condensing lens and focused by a projection lens. It passes through a narrow slit on to the sound track of the film. As the film passes over the photo-electric cell varying amounts of light pass through the sound track into the photo-electric selenium cell. This cell changes light variations into electric-current variations. These pulses of electricity are intensified by the amplifiers so that they can work the loud speaker, just as pulses of electricity operate the receiver in the telephone.

The Smoother eliminates the tendency of the film to run irregularly.

The Loud Speaker. For large school halls and those having unfavourable acoustic properties (most school halls are in this

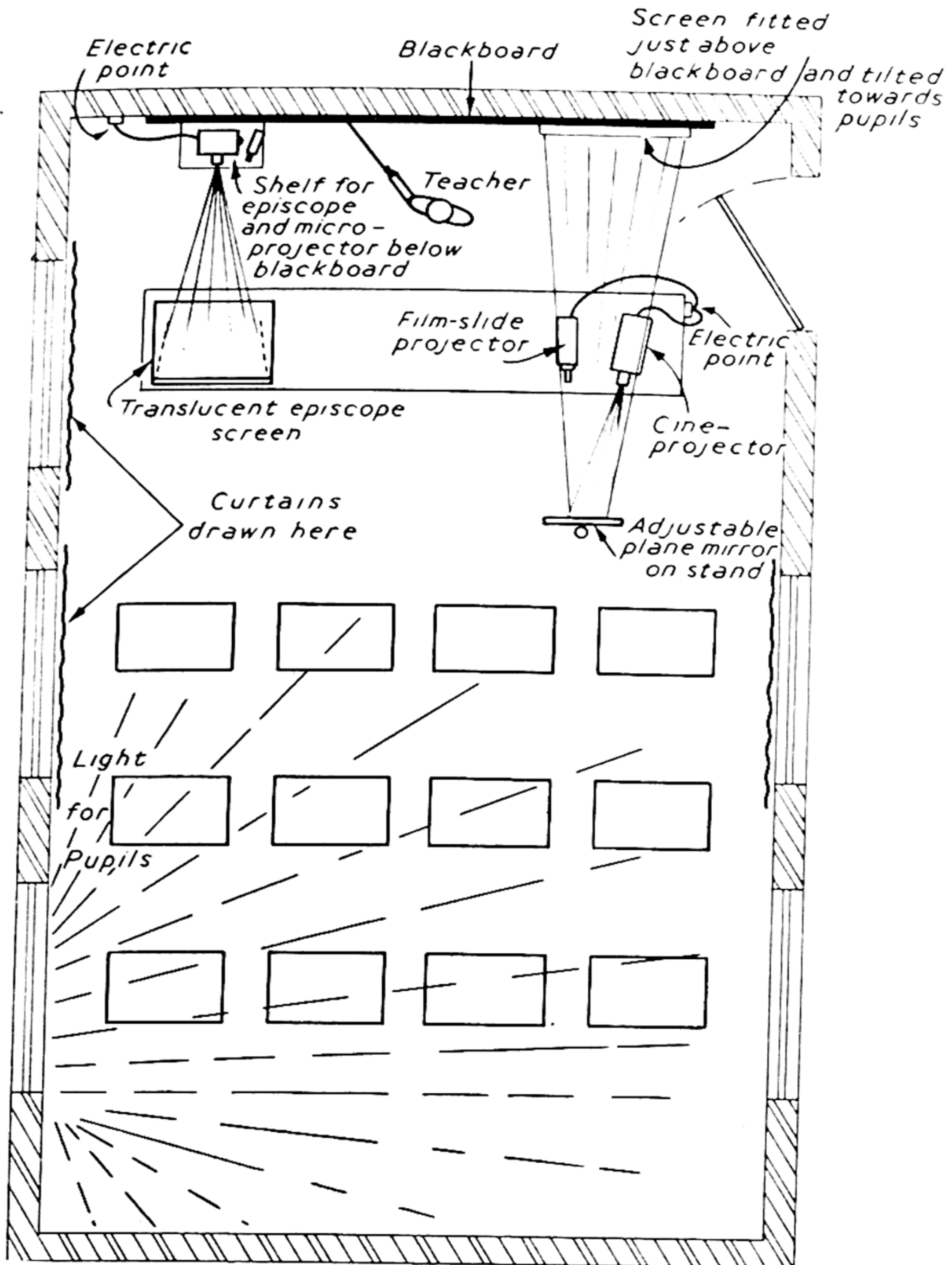


FIG. 146. ARRANGEMENT OF OPTICAL-AIDS ROOM

category, since acoustics were not considered when the older schools were designed) a directional funnel should be fitted to the

loud speaker. This will direct the sound towards the audience, and avoids reflections from side-walls.

The Use of the Optical Aids

In the new schools which are planned for the future no doubt experts will be consulted so that the best arrangements can be made, particularly with regard to acoustics, for the use of optical aids in all rooms.

I am concerned here with the use of such aids under the conditions existing in our schools at the present time.

Perhaps the most satisfactory arrangement is to have all available projectors and screens more or less permanently mounted in one room, if a room can be set aside for this purpose—*e.g.*, the science lecture room. Much time is wasted, and there is a much greater risk of damage, if equipment has to be carried about, set up, and taken down too often,

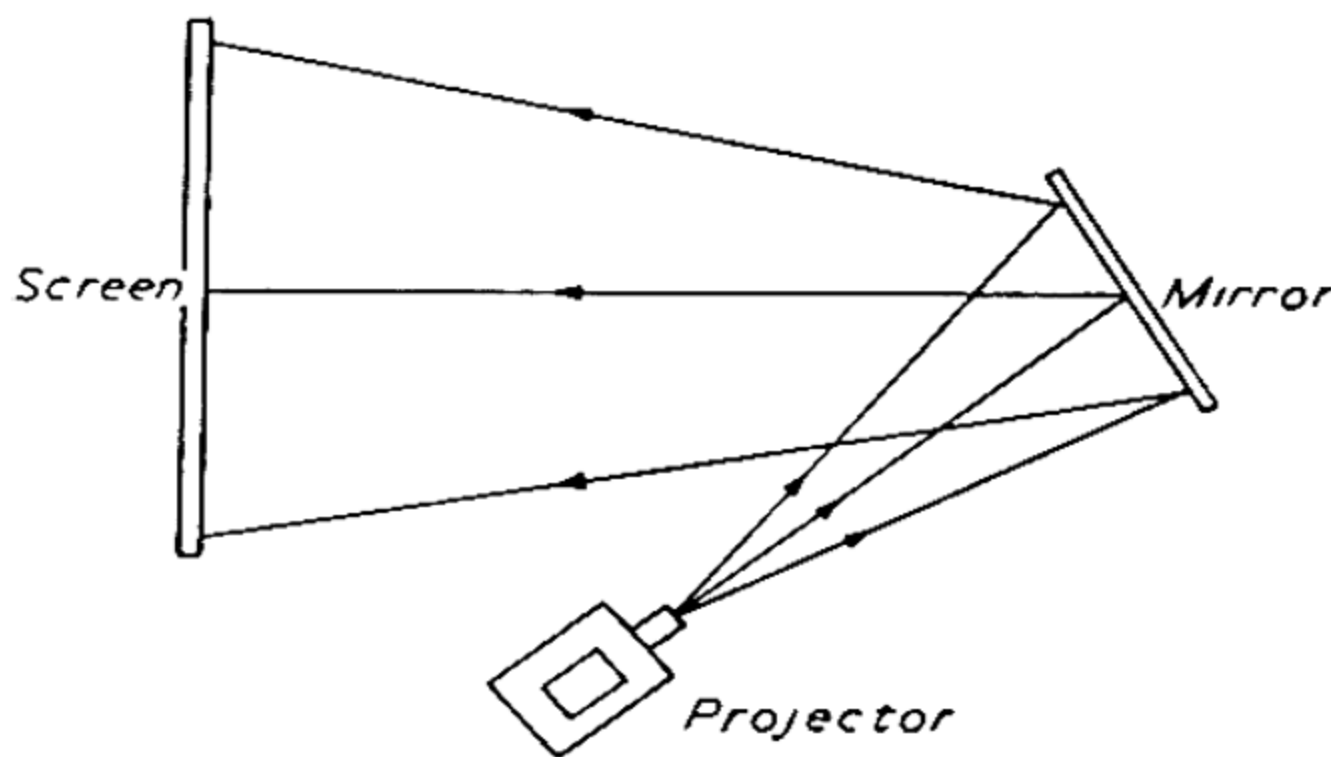


FIG. 147. ARRANGEMENT OF PROJECTOR AND MIRROR IN RELATION TO SCREEN

If there is a spare room, so much the better. This can be fitted up as the optical-aids room, and

classes can move in for films, film-strips, etc. Dust-covers would be necessary for the equipment, and they would have to be protected from interference by prying hands or inexperienced persons.

It should not be necessary to darken the room completely, and it should certainly not be necessary to shut all windows and draw all curtains, while projectors are in use.

The teacher's place is in front of the class, where he can see all his pupils. He must be near the projector, the blackboard, and the screen. The pupils should be able to make notes and diagrams if necessary. With good screens, suitably placed away from direct light, and with high-wattage lamps in the projectors, all the above conditions can easily be complied with. The diagram illustrates a method of doing this.

The film-strip projectors can be used in all classrooms in the school by mounting the projector and mirror on a horizontal board which can easily be carried around, and painting one surface of a black-board flat white to serve as a screen.

A flat-white screen is best for use with the film-strip and cine-projectors and a translucent screen for the episcopes and micro-projector. Light from the projector should always fall as near perpendicularly as possible on to the screen, as illustrated in Fig. 147.

The wall, provided the surface is good, painted flat white, or a large sheet of white drawing-paper, makes a good screen, with a wider angle of clear vision than the silver surfaced screens.

A translucent screen for the episcopes can be made from Celastoid sheet, a product of British Celanese, Ltd. Sheets 49 in. $\times$ 21 in.

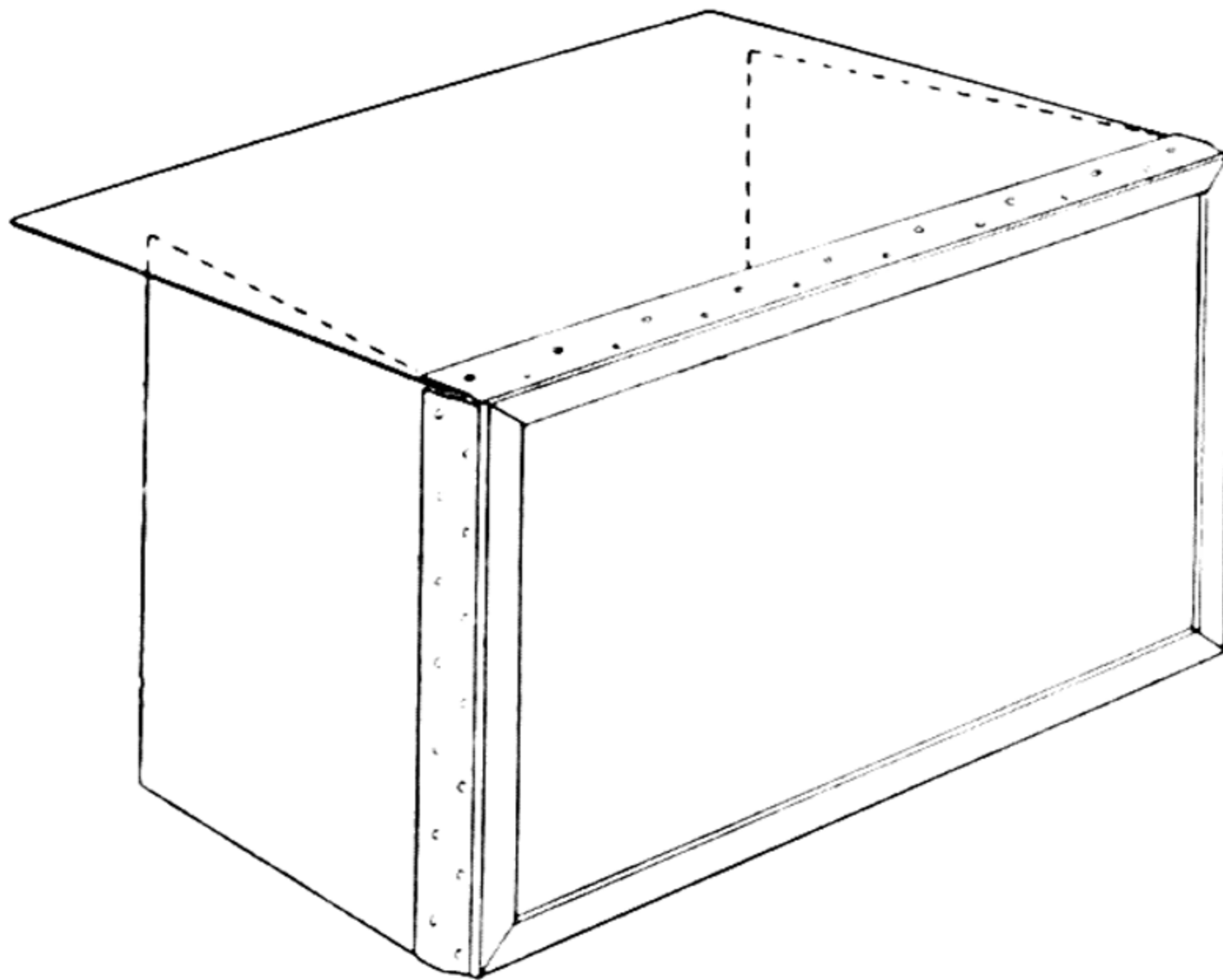


FIG. 148. TRANSLUCENT SCREEN

can be obtained from Messrs Newton and Co., Ltd, 72 Wigmore Street, London, W.1. This sheet Celastoid can be fixed to a picture-frame, which can be made into a screen by fitting plywood side-pieces and a cover with webbing, as illustrated. All wooden parts of this screen should be painted dead-black with a solution of lamp-black and shellac in methylated spirit.

If the projectors, screens, and accessories must be carried round the school from room to room it is a good plan to mount the whole lot on a specially built trolley with large rubber-tyred wheels.

The greatest care must be taken to avoid jolting lamp filaments and valves.

Sources of 16 mm. Films, Film-strips, and Episcopes Pictures

Catalogues and lists of films can be obtained from all the addresses given below. These lists usually give sufficiently detailed descriptions of the films and film-strips to enable teachers to decide on their suitability

for use in connexion with their lessons. Some of the films can be borrowed free of charge.

Film-strips can usually be obtained on approval by local viewing groups of teachers.

16 mm. Sound and Silent Films

Austin Motor Company, Ltd, Longbridge Works, Birmingham.

Boy Scouts' Association, 25 Buckingham Palace Road, London, S.W.1.

British Film Institute, 164 Shaftesbury Avenue, London, W.C.2.

(Film Institute Collection and the National Film Library.)

British Instructional Films, Ltd, Film House, Wardour Street, London, W.1.

British Red Cross Society, 14 Grosvenor Crescent, London, S.W.1.

British Rubber Development Board, Market Buildings, Mark Lane, London, E.C.3.

Central Film Library, Imperial Institute, South Kensington, London, S.W.7.

(This library of films, available on free loan, includes the Empire Film Library, the G.P.O. Film Library, Ministry of Information Films, and Central Office of Information films.)

Cine Equipments, Ltd, 35 Colmore Road, Birmingham, 3.

Cunard White Star, Ltd, Liverpool.

Educational and General Services, Ltd, Tower House, Woodchester, Near Stroud, Gloucestershire.

Electrical Association for Women, 20 Regent Street, London, S.W.1.

Food Education Society, 29 Gordon Square, London, W.C.1.

Gateway Film Productions, 84 Powys Lane, Palmers Green, London, N.13.

G.B. Film Library, Aintree Road, Perivale, Middlesex.

(This library includes educational films for the classroom and entertainment films. An enlarged edition of the annotated G.B. Instructional Film Catalogue giving details of over 400 films can be obtained on application. All educational films are classified in age-groups.)

Girl Guides' Association, 17 and 19 Buckingham Palace Road, London, S.W.1.

Health and Cleanliness Council, 5 Tavistock Square, London, W.C.1.

Morris Motors, Ltd, Cowley, Oxford.

National Association for the Prevention of Tuberculosis, Tavistock House, Tavistock Square, London, W.C.1.

National Ophthalmic Treatment Board, 90 Tavistock House, Tavistock Square, London, W.C.1.

People's League of Health, 10 Stratford Place, London, W.1.

Petroleum Films Bureau, 15 Hay Hill, Berkeley Square, London, W.1.

Sound Services, Ltd, 269 Kingston Road, Merton Park, London, S.W.19.

The Army Kinema Corporation, West Huntington Hall, Huntington, York.

The British Electrical Development Association, 2 Savoy Hill, London, W.C.2.

The British Gas Council, 1 Grosvenor Place, London, S.W.1.

The Central Council for Health Education, Tavistock House, Tavistock Square, London, W.C.1.

The Coal Utilization Joint Council, 54 Victoria Street, London, S.W.1.

The Educational Films Bureau, 5 Walton Terrace, Aylesbury, Bucks.

The Royal Society for the Prevention of Accidents, Terminal House, 52 Grosvenor Gardens, London, S.W.1.

The Royal Society for the Prevention of Cruelty to Animals, 105 Jermyn Street, London, S.W.1.

Universities Federation for Animal Welfare, 169 Strand, London, W.C.1.

Wallace Heaton, Ltd, 127 New Bond Street, London, W.1.

Cyclic Films

Cinepro, Ltd, 1 New Burlington Street, London, W.1.

Dance-Kaufmann, 18 Upper Stanhope Street, Liverpool, 8.

Film-strips

British Industrial Films, Ltd, 183 King's Road, Chelsea, London, S.W.3.

British Instructional Films, Ltd, Wardour Street, London, W.1.

Daily Mail School Aid Dept., New Carmelite House, Carmelite Street, London, E.C.4.

Educational Productions, Ltd, 17 Denbigh Street, Pimlico, London, S.W.1.

Educational Supply Association, Ltd, 181 High Holborn, London, W.C.1.
(Common Ground Film-strips.)

G.B. Film Library, Aintree Road, Perivale, Middlesex.

Newton and Co., Ltd, 72 Wigmore Street, London, W.1.

The Army Kinema Corporation, West Huntington Hall, Huntington, York.

Unicorn Head Visual Aids, Ltd, 40 Broadway, Westminster, London, S.W.1.

Visual Information Service, 168a Battersea Bridge Road, London, S.W.11.

Pictures for the Episcopes

A. and C. Black, Ltd, Publishers, 4, 5, and 6 Soho Square, London, W.1.

J. Salmon, Ltd, Art Publishers, Sevenoaks, Kent.

National Gallery, Trafalgar Square, London, W.C.2.

National Portrait Gallery, St Martin's Place, London, W.C.2.

The British Museum, Bloomsbury, London, W.C.1.

The London Cigarette Card Company, Ltd, 30 Wellesley Road, Chiswick, London, W.4.

The Natural History Museum, Cromwell Road, South Kensington, London, S.W.7.

The Science Museum, Exhibition Road, South Kensington, London, S.W.7.

The Tate Gallery, Millbank, London, S.W.1.

Victoria and Albert Museum, South Kensington, London, S.W.7.

The Central Office of Information

The Central Office of Information is continuing the work of the war-time Ministry of Information from Regional Offices in various parts of the country. During the war years, and since then, the Film Officer at the North Regional Office has been willing to send into schools, by arrangement, projectors, films, operators, and screens. A list of films available will be sent on request, and an operator, with equipment, will be supplied to project films obtained from other sources for school work, if required, in addition to C.O.I. films.

Further Information

Catalogue of Visual Aids: *Films and Filmstrips*, Parts I to IV: For Secondary Schools (Educational Foundation for Visual Aids, 33 Queen Anne Street, London, W.1).

DALE, E.: *Audio-visual Methods in Teaching*.

DANCE, H. R., AND I.W.: *An Introduction to Film Strips*.

LAUWERYS, J. A.: *The Film in the School*.

MEREDITH, G. P.: *Visual Education and the New Teacher*.

Optical Aids (Board of Education Pamphlet No. 115 (1938)).

Survey of Pictorial Materials: *Films and Filmstrips* (National Federation of Educational Film Groups. From The Secretary, Colmers Farm School, Rubery, Birmingham).

The Assessment of Educational Films (University of London Press).

Visual Aid Year Book (Daily Mail School Aid Department).

Publications of the British Film Institute for Teachers, 4 Great Russell Street, London, W.C.1:

Choosing School Projectors.

Films Suitable for Youth Organizations.

Teaching with School Projectors.

Using School Projectors.

SCHOOL-MADE OPTICAL AIDS

WITH care and patience it is possible to make episcopes, optical lanterns, film-slide projectors, and micro-projectors, which will give reasonably good results, at a fraction of the cost of manufactured instruments.

A Model Episcope

Figs. 149, 150, and 151 illustrate a method of making an episcope, which will give highly satisfactory results, for an outlay of about £8, which is about one-fifth of the cost of a manufactured instrument. It is used, as described in Chapter V, with a translucent screen. Eight-millimetre plywood is used in its construction, and pieces should be cut to the sizes indicated, allowing for the thickness of the plywood.

After drilling the necessary ventilation holes and cutting out the holes for the picture-holder, lamps, lens, and ventilators, the sides, top and bottom, and front and back are simply screwed together with brass round-headed screws. Before doing this the pieces should be held together with a few panel pins, and holes should be made for the screws with drill and bradawl.

The hole for the lens—the size of which will depend on the size of the lens obtained—must be made in the centre of the front. A suitable episcope lens, $2\frac{3}{8}$ in. diameter and 8 in. focus, can be obtained from the British Optical Lens Company, 315 Summer Lane, Birmingham, 19.

The front, top, and bottom, and the sides should be painted white on the inside, or, better still, lined with white asbestos. The inside of the back, including the inside of the picture-holder, should be painted dead black with a solution of lamp-black and shellac in methylated spirit. The outside may be covered with two or three coats of shellac. Pieces of plane mirror are also fixed on the insides of the top and bottom and the sides.

The lamps are 230-volt, 250-watt tubular vertical-burning lamps with E.S. cap.

The picture-holder is held in position by two narrow strips of wood fixed along the inside of the upper and lower edges of the picture opening. A knob is fixed to the back of the picture-holder for removing and replacing it, and a ball-and-socket catch holds it in position.

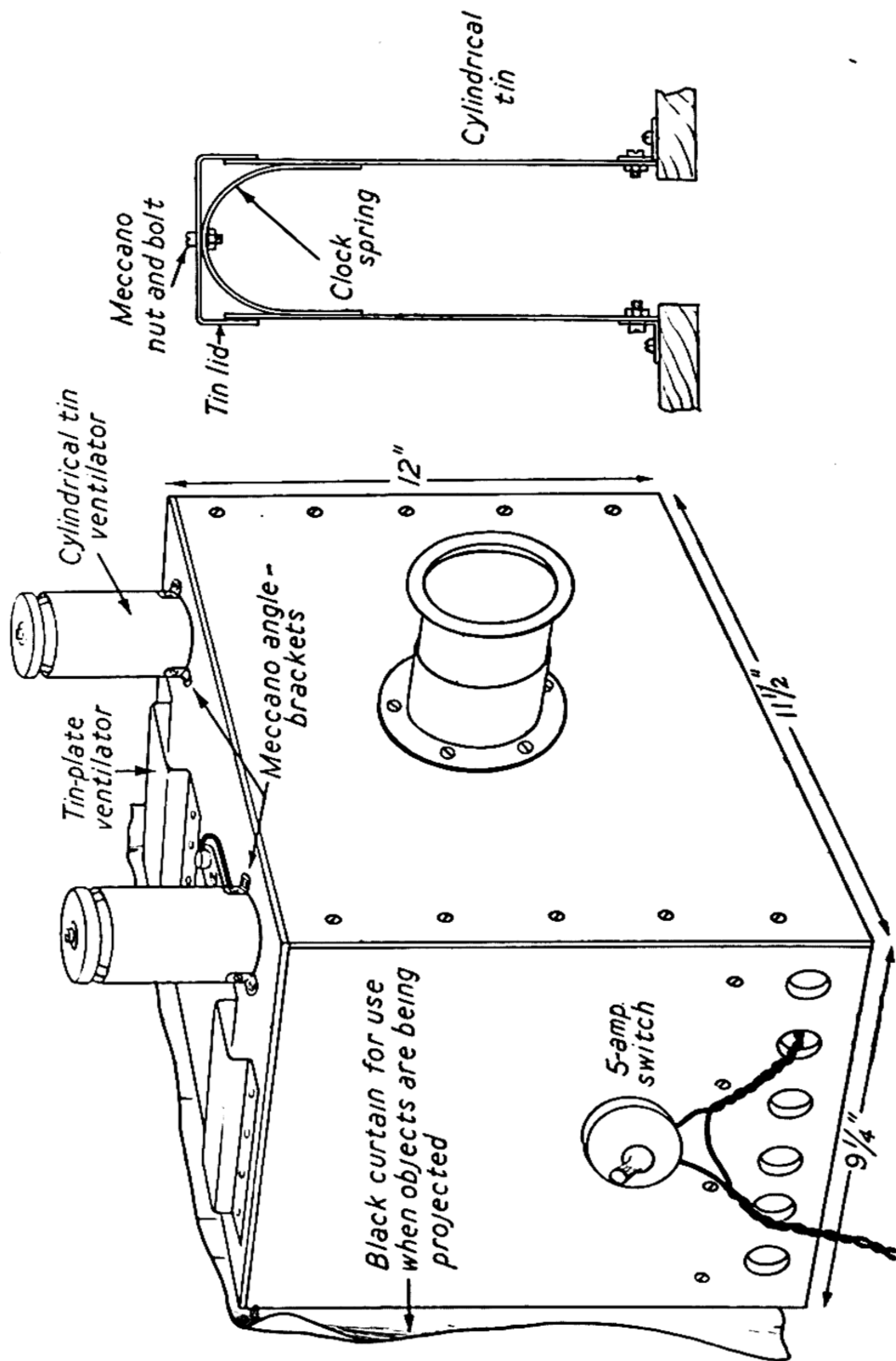


FIG. 149. MODEL EPISCOPE

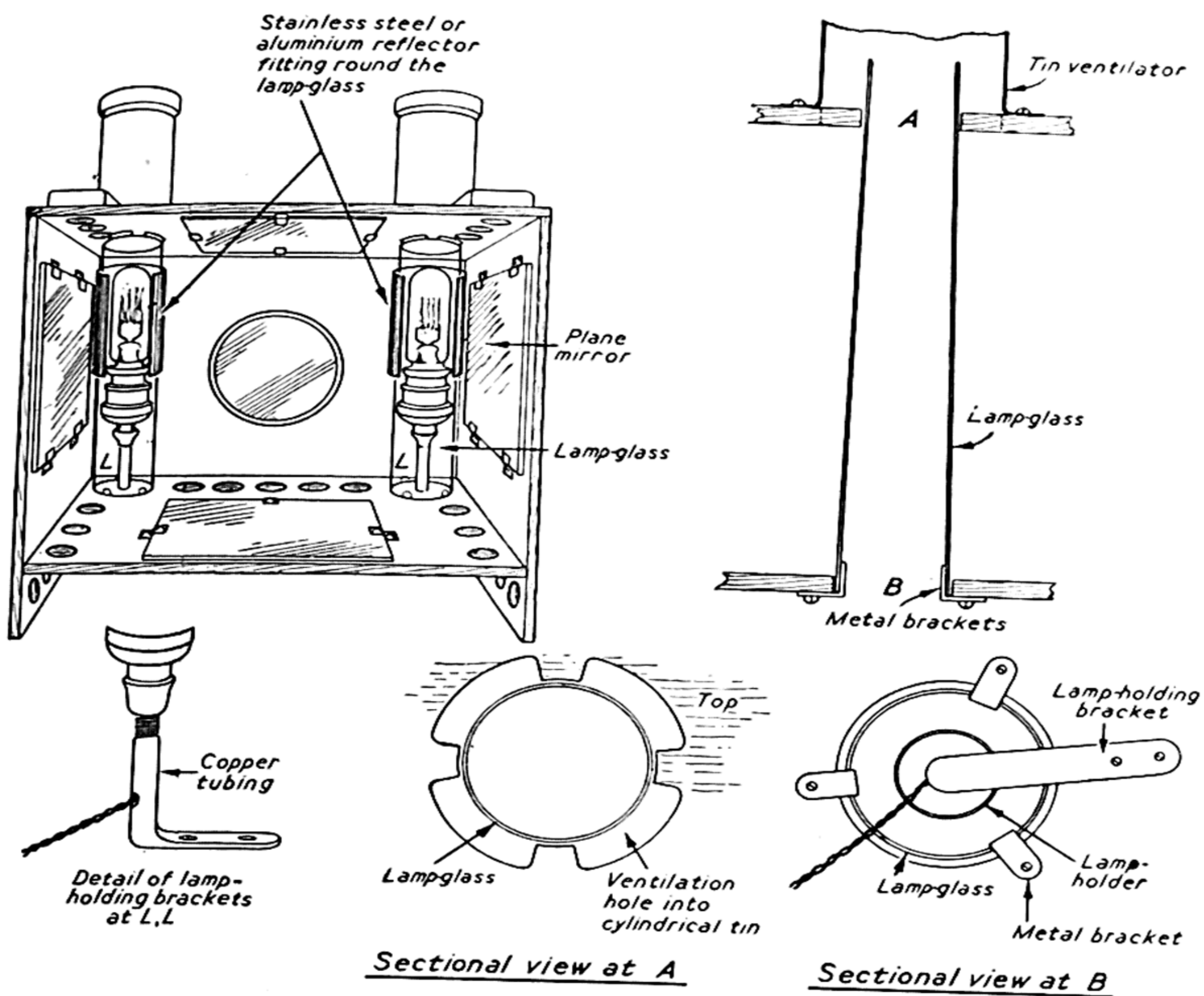


FIG. 150. MODEL EPISCOPE

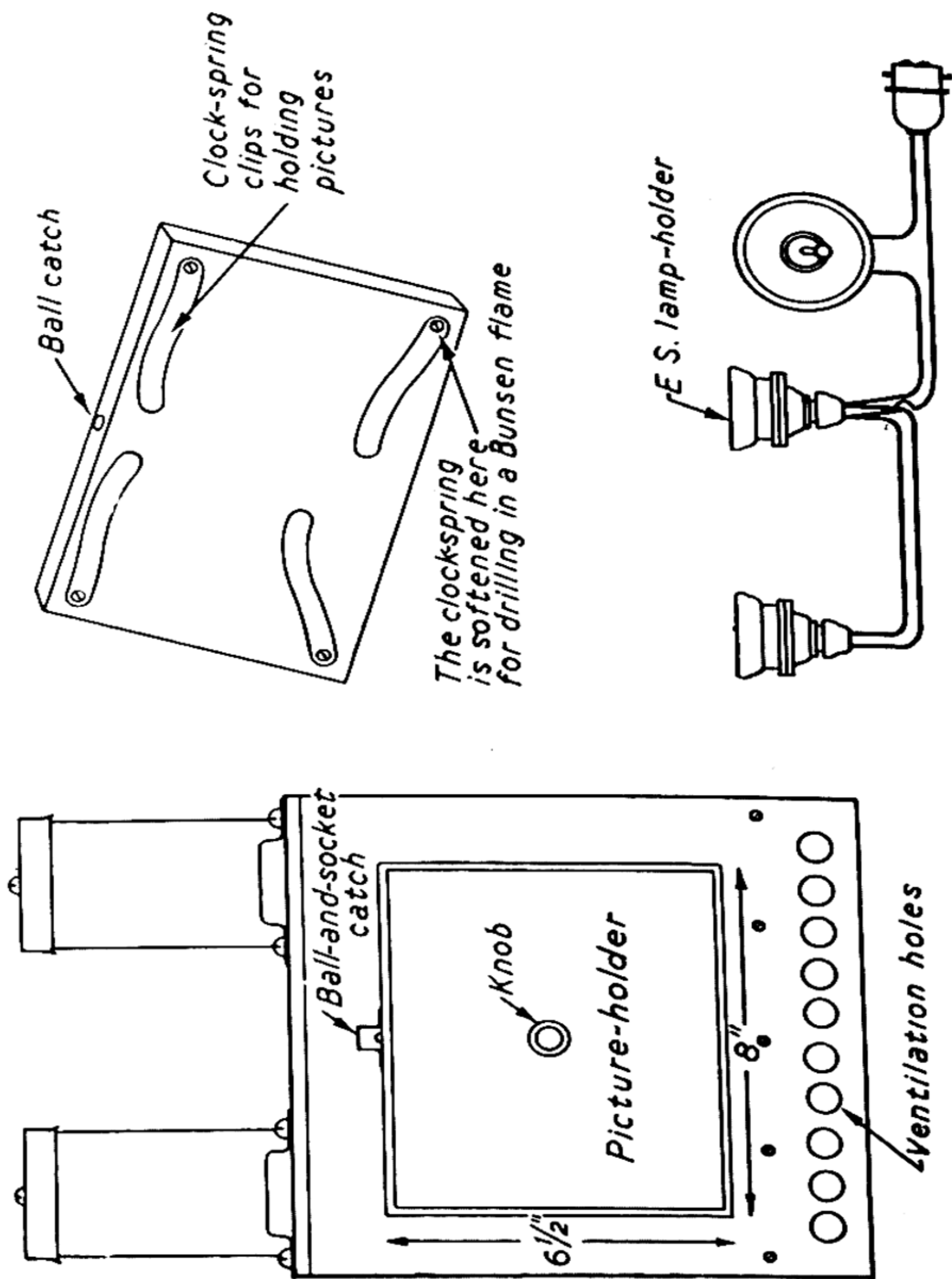


FIG. 151. MODEL EPISCOPES

When projecting objects or the pages of large books or maps, these can be held against the picture opening or they can be placed on the bench with the episcope over them, as shown in Fig. 152. The episcope can then be removed about over the picture until the whole of it is projected, but the apparatus should not be kept in this position longer than is absolutely necessary, as the lamps are intended to be burned vertically.

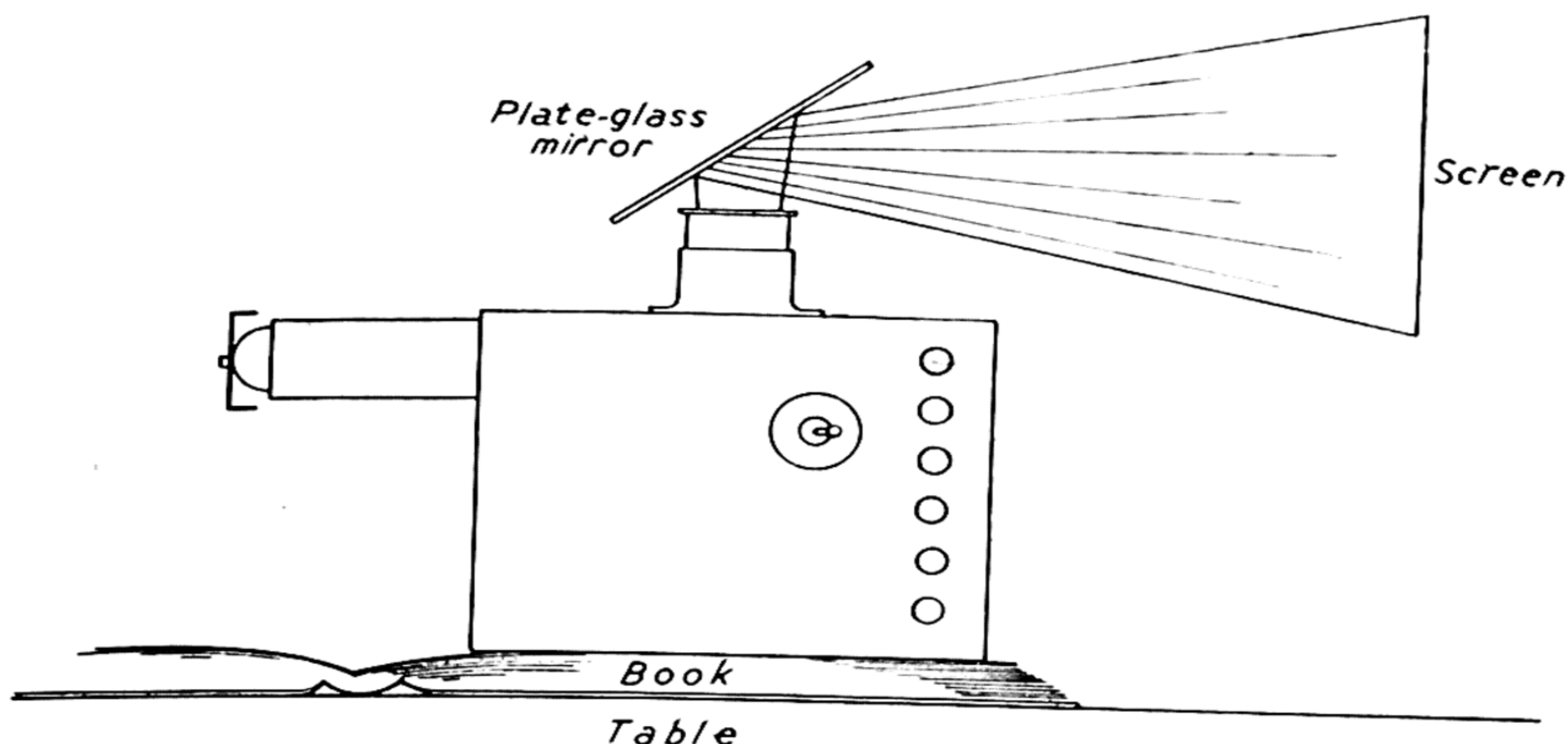


FIG. 152. PROJECTING LARGE PICTURES

Film-strip Projectors

Many schools already possess an optical lantern. Such a lantern has many uses in the science room in addition to that originally intended for it. By making slight modifications and additions it can be converted into an excellent film-strip projector, and it can also be used for many delightful demonstration experiments, such as throwing on to a screen enlarged pictures of magnetic fields, convection currents in liquids, and electrolysis experiments.

To convert your lantern into a film-strip projector, make the film-strip adaptor illustrated in Fig. 153. It is made from pieces of plywood and other odds and ends. The method of assembling will be clear from the diagrams.

The adaptor is fitted into the optical lantern in the position usually occupied by the lantern-slide holder. The spaces cut away enable this to be done with most types of lantern.

The film-strip is placed on the brass tube, which revolves freely on the dowell rod, allowing the strip to be taken up on the wooden

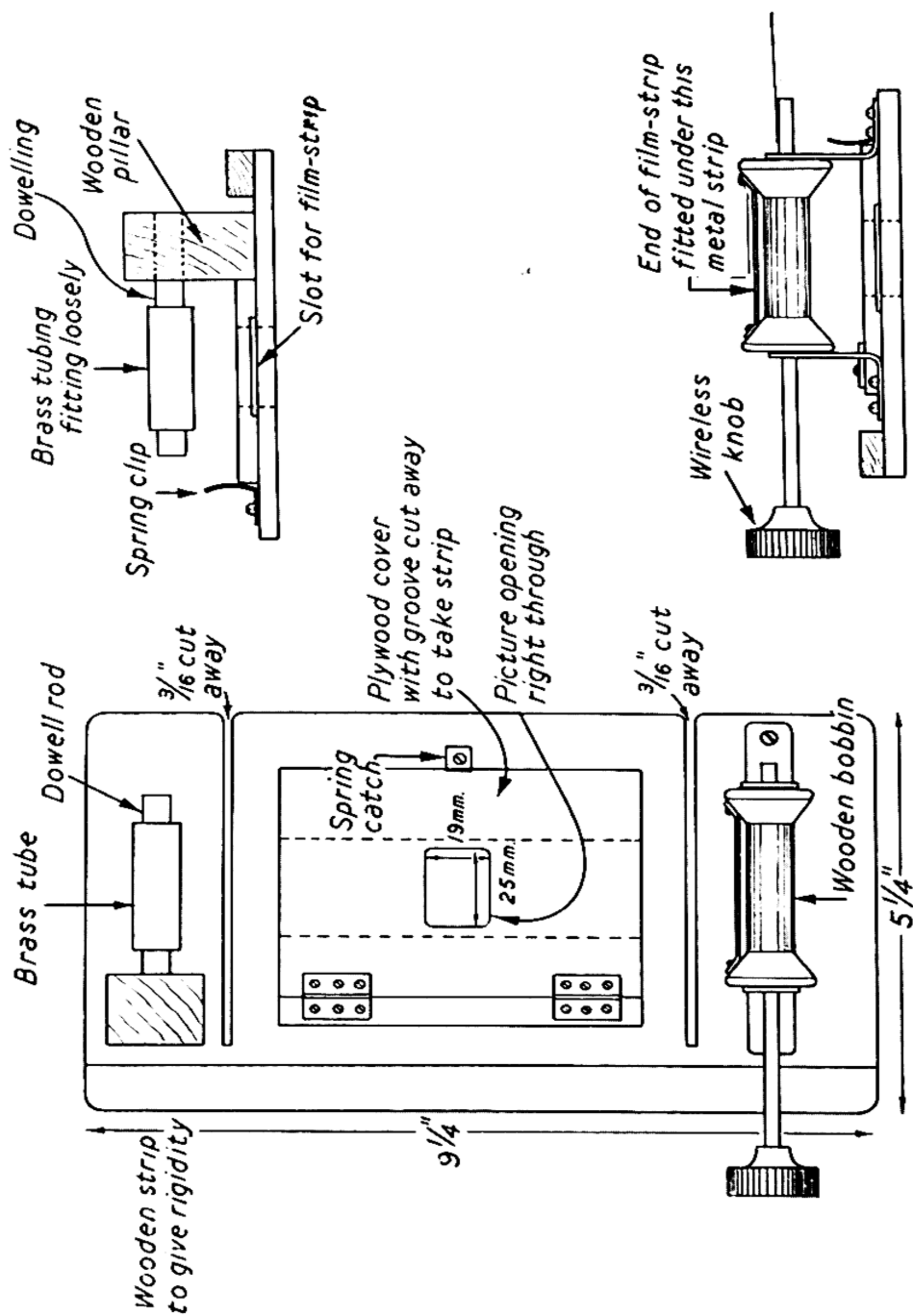


FIG. 153. FILM-STRIP ADAPTOR

bobbin after it has passed over the picture opening along the groove made by removing one layer of the plywood cover.

The picture opening occupies about one-tenth of the area occupied by an ordinary lantern-slide, and the picture on the screen is accordingly one-tenth of the size of the picture produced with such a lantern-slide, with the same objective and the same distance between screen and projector. To enlarge the picture the distance between screen and projector can be increased, or, if this must be kept constant, a shorter focal-length objective must be used. For an optical lantern with lantern-slides the objective should have a focal length of about 8 in.; for the same lantern, screen, and distance between screen and projector when projecting film-strips an objective of about 5 in. focus should be used.

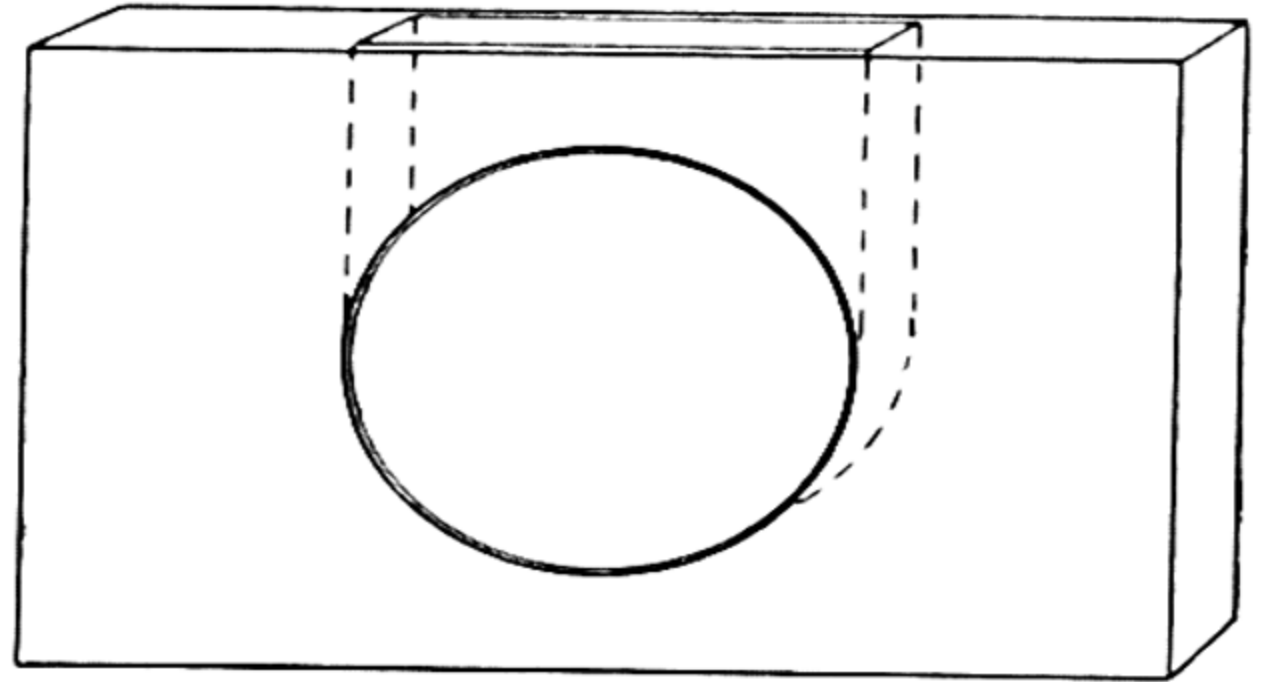


FIG. 154. TROUGH FOR PROJECTING

Methods of projecting on to a screen enlarged images of magnetic fields, convection currents in liquids, and electrolysis with the aid of an optical

lantern and a special trough have already been referred to in this book and in *Everyday Science Topics*, Book III. These are fascinating experiments. The trough, Fig. 153, can be purchased for a few shillings from A. Gallenkamp and Co., Ltd, 10 Clifton Street, Finsbury Square, London, E.C.2.

It consists of a piece of mahogany 7 in. $\times$ 4½ in. with a circular opening 3 in. in diameter. This opening is provided with two glasses, separated by stout rubber. The trough fits into the place provided for the lantern-slide holder in the lantern.

For those who do not possess an optical lantern the simple model lantern illustrated in Fig. 155 is ideal for conversion into a film-strip projector, in addition to the projection of ordinary lantern-slides. It can also be used for the projection of magnetic fields, electrolysis, and convection currents, and is quite easily made.

Various sources of light can be used with success in the lamp house. An ordinary 150-watt electric lamp gives quite good illumination, provided it is carefully adjusted before fixing to give maximum illumination on the screen. I am at present using one of Gallenkamp's Focuslite outfits, No. 1B. This has a 230-volt, 250-watt lamp with a plain tray.

The lamp house is made of tin plate painted dead black inside and out. The hole in the front is 2 in. in diameter. The condenser and

objective are fixed by means of brass strips to pieces of wood having centre pieces projecting down into the groove which runs along the centre of the stand. This enables the condenser and objective to be moved backward and forward along the groove. The condenser should be pushed as near as possible to the hole in the front of the lamp house, and the side-pieces *A* and *B* should be fixed just in front

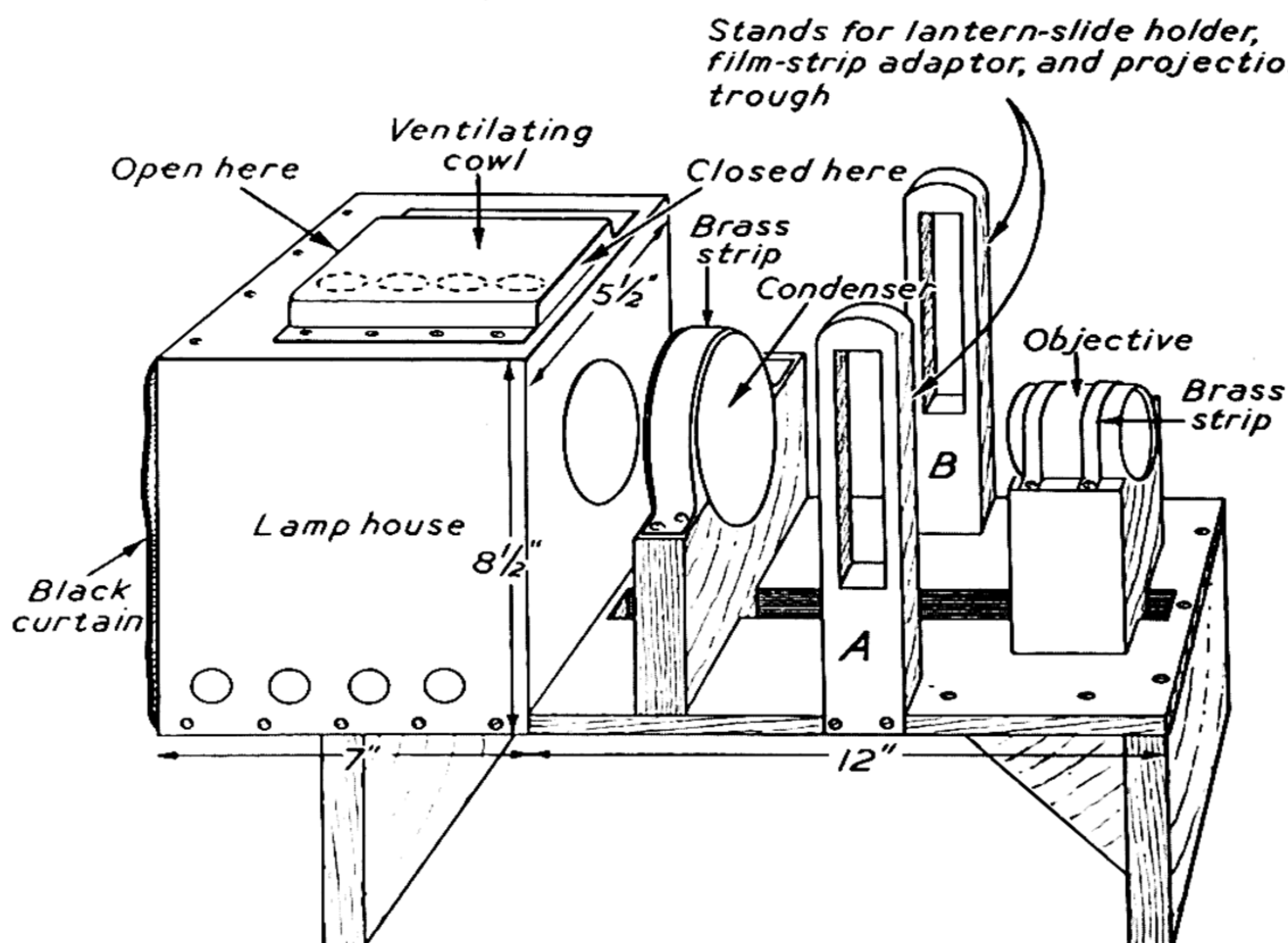


FIG. 155. MODEL OPTICAL LANTERN

of the condenser. (In the drawing they are shown apart for clearness.) The objective can then be moved backward and forward for focusing through a considerable distance. It is most important that an imaginary straight line drawn through the centres of the lamp-house hole, the condenser, the centre of the diapositive, and the objective lenses, should be horizontal.

Micro-projectors

When enlarged images of small living creatures and microscopic structure have to be shown the micro-projector provides the best means, as the teacher, when using it, can be certain that the pupils have seen what he wishes them to see. This cannot be ensured by the use of a microscope, and much time is lost in large classes if each child has to

look in turn. A micro-projector should be part of the equipment of every secondary school. These pieces of apparatus are expensive, but they can be improvised.¹

With a micro-projector pupils may be shown some of the wonders of the invisible world. It renders the purchase of a number of microscopes unnecessary. A whole class can view the object under discussion at one and the same time without having to crowd round the demonstration table. Living specimens or permanently mounted slides may be projected on to a screen for a large group to see, or on to a page of a notebook laid on the bench for tracing with a pencil.

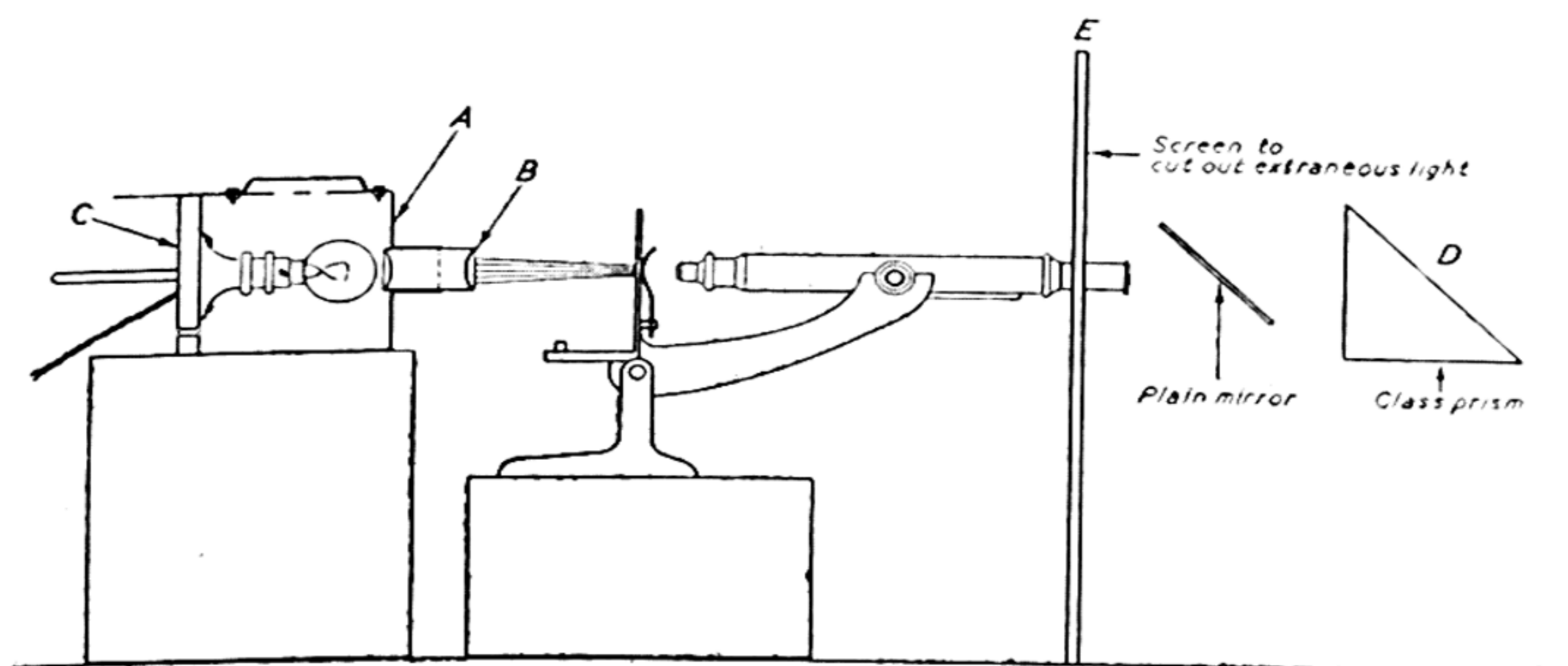


FIG. 156 (a). MICRO-PROJECTION

Any good-quality microscope, the body tube of which can be placed in a horizontal position, can be converted into a micro-projector. A motor-car headlamp bulb, suitably mounted, will provide the necessary illumination. A simple method of doing this is illustrated in Fig. 156 (a). The microscope is placed on a box, and the substage mirror is removed.

A is a rectangular tin box, the inside of which is painted dead-black. A circular hole is cut in the base of the tin box, and to this is soldered a short piece of brass tube which supports the condenser B, so that it is a good sliding fit in the tube. A good condenser should be purchased, and this should be placed as near to the glass of the lamp as possible.

The method of mounting the lamp on a wooden base is also illustrated. If a 6- or 12-volt motor-car headlamp is used this should be of the two-pin type, and it can be held in a batten-mounting type of lamp-holder screwed to the piece of wood, C. Better illumination is obtained if a 6-volt, 4-ampere, concentrated filament

¹ *Suggestions for Teachers* (Board of Education).

projection lamp with Edison screw cap is used. An Edison screw type lamp-holder will be necessary, and a hole will have to be made in the wood *C* to hold the lamp-holder, as shown in the smaller illustration.

An Edison screw type lamp-holder and projection lamp can be obtained from Philips Electric Lamps, Ltd, Century House, Shaftesbury Avenue, London, W.C.2, or the General Electric Company, Ltd, Magnet House, Kingsway, London, W.C.2. Ventilation holes are drilled near the lower edge of *C* and in the upper surface of the tin *A*.

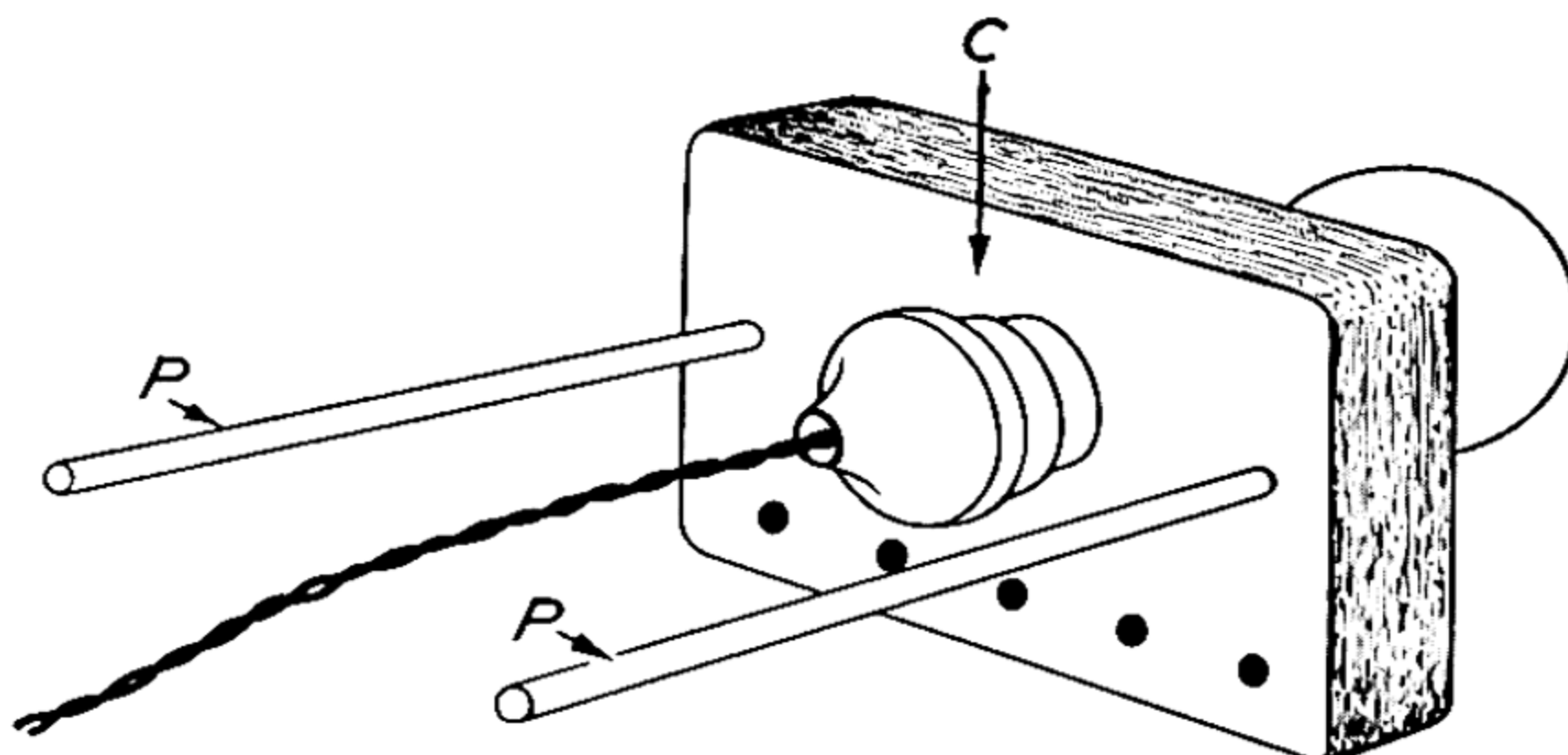


FIG. 156 (b). MICRO-PROJECTOR LAMP-HOLDER

The holes in *A* are covered with a piece of tin plate, held in position with four Meccano nuts and bolts to prevent the escape of light. The edges of *C* are covered with felt glued to the wood to make it a good sliding fit inside the tin, and *P, P* are pieces of dowelling glued into holes drilled in *C* so that it can be moved backward and forward for focusing.

By adjusting the positions of the condenser *B* and the lamp a small circle of intense light can be focused on the microscope slide, live box, or aquarium held on the microscope stage. It is important first, however, to get the optical axis of the microscope in line with that of the condenser. This can be done by removing the slide from the stage and focusing the circle of light on the screen until it is uniformly illuminated.

The screen may consist of a sheet of white paper or cardboard, or a piece of tracing-paper or Celestoid held in a picture frame. Celestoid can be obtained from Newton and Company, Ltd. If the screen is made from translucent material, the operator may stay at the back of it and the pupils may be placed in front. The space between the microscope eyepiece and the translucent screen may be boxed in with a wooden frame covered with thick brown paper (Fig. 157). If the screen is set back a little from the front opening of this

arrangement, daylight projection can be obtained. If ordinary white paper or cardboard is used for a screen, the room must be darkened.

It is important that the screen be placed perpendicular to the microscope tube, for a slight obliquity will throw the image out of focus on one side.

The daylight projecting arrangement is shown with the brown-paper covering removed. The size of this depends on the size of the image required. It is important to keep in mind that the total amount of light falling on the screen is always the same, and that if we increase the area of the projection we have to distribute the same amount of light over a larger surface, and the brilliancy will be reduced. Indeed, this apparatus can be used to show why the intensity of illumination on a surface diminishes with increased distance from the source of light. *A* is the hole for the microscope eyepiece, and the translucent paper screen is pinned to the frame *B* (Fig. 157).

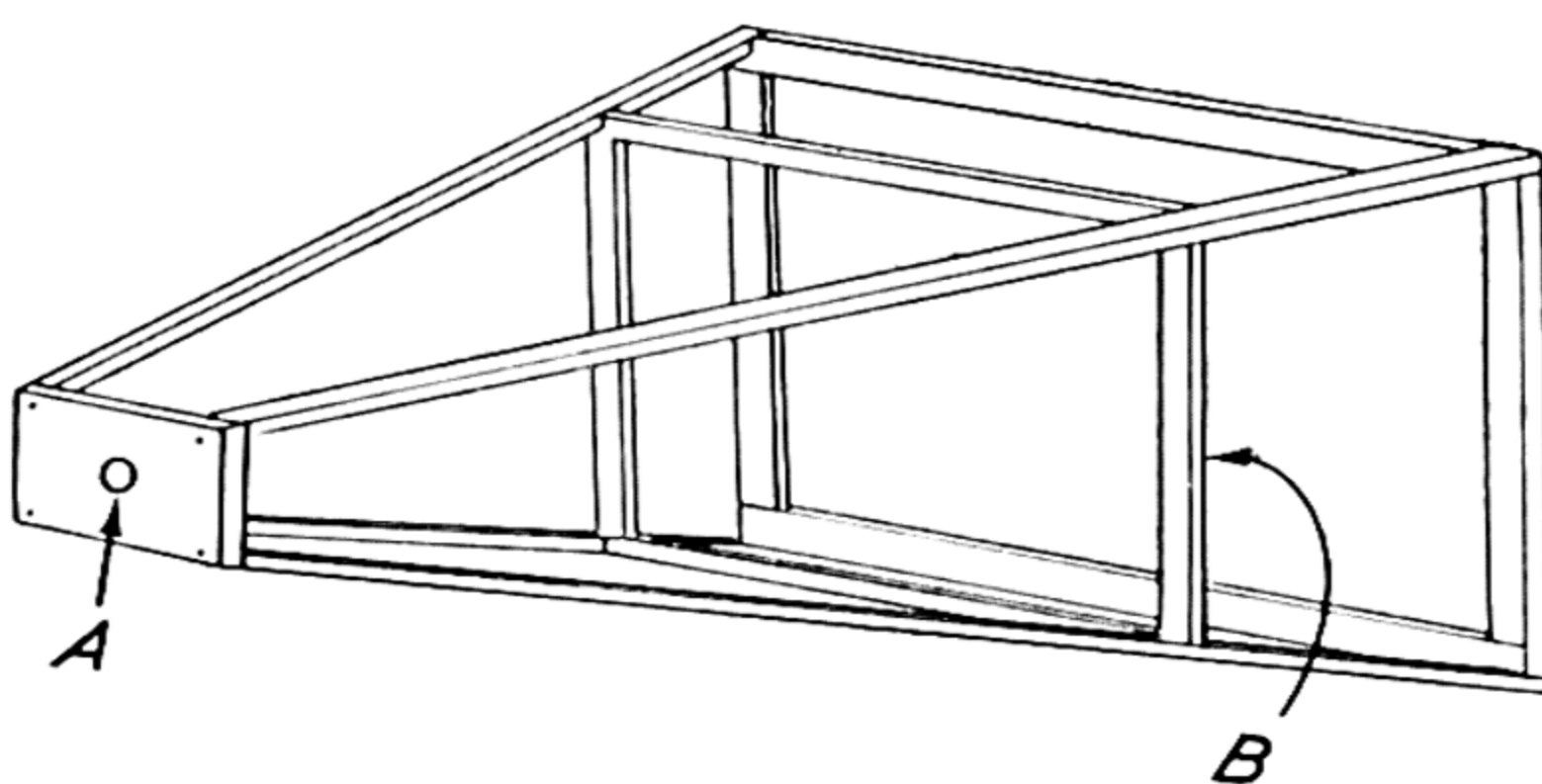


FIG. 157. WOODEN FRAME TO BE COVERED WITH PAPER FOR DAYLIGHT PROJECTION

When the best positions of the microscope and lamp house have been found they should be firmly fixed in these positions. The microscope slide can then be placed in position, and the microscope focused in the usual way.

An excellent live box for the projection of living specimens, such as daphnia, rotifers, etc., can be made very simply by inserting a piece of sheet rubber from an old inner tube with a piece *A* cut away between two glass slides. This may be used in the same way as an ordinary slide on the microscope stage, and the space *A* is filled with liquid (Fig. 158).

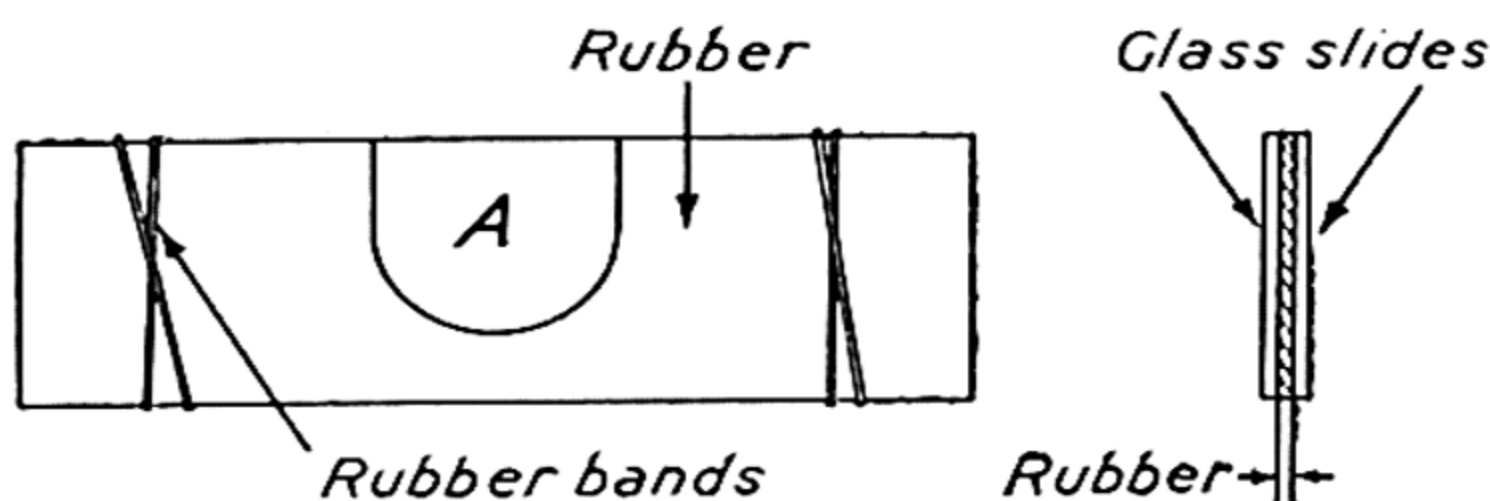


FIG. 158. MICRO-PROJECTOR LIVE BOX

To project the image on to a page of a notebook or a sheet of drawing-paper placed horizontally for tracing with a pencil, a piece

of plane mirror, or, better still, a right-angled glass prism, should be placed near the eyepiece of the microscope, as indicated at *D*. The mirror or prism can be held in a retort-stand clamp.

If the image from the microscope is projected on to an opaque screen or on to the page of a notebook, it may be necessary to prevent

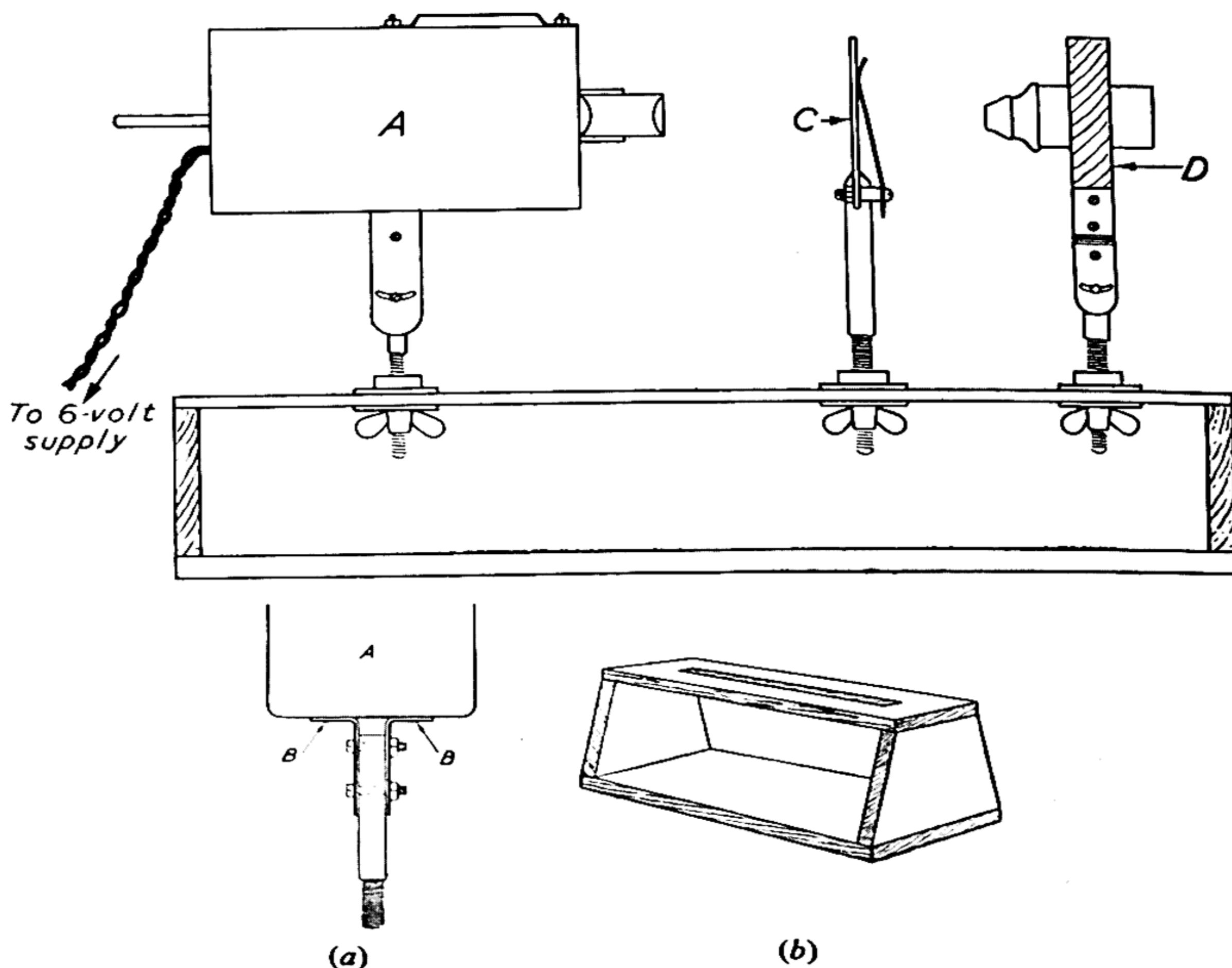


FIG. 159. MODEL MICRO-PROJECTOR

- (a) Method of supporting lamp-house and condenser.
 (b) The wooden stand.

extraneous light from falling on to the screen or notebook from the lamp house or other sources. This can usually be done by placing round the screen or notebook a plywood screen, and a sheet of plywood, with a small hole cut in it to allow the microscope eyepiece to pass through, should be placed at *E* (Fig. 156 (a)).

Constructing a Micro-projector

A method of converting any good-quality microscope into a micro-projector has just been described. There may be many schools

without such a microscope. For such schools the model micro-projector shown in Fig. 159 would be ideal. Carefully made, it will give results comparable with those given by many manufactured instruments.

The wooden stand has been designed so that the image may be projected on to a vertical screen or a horizontal surface like a ceiling or a sheet of white paper on the bench. The method of constructing the lamp house *A* has already been described and

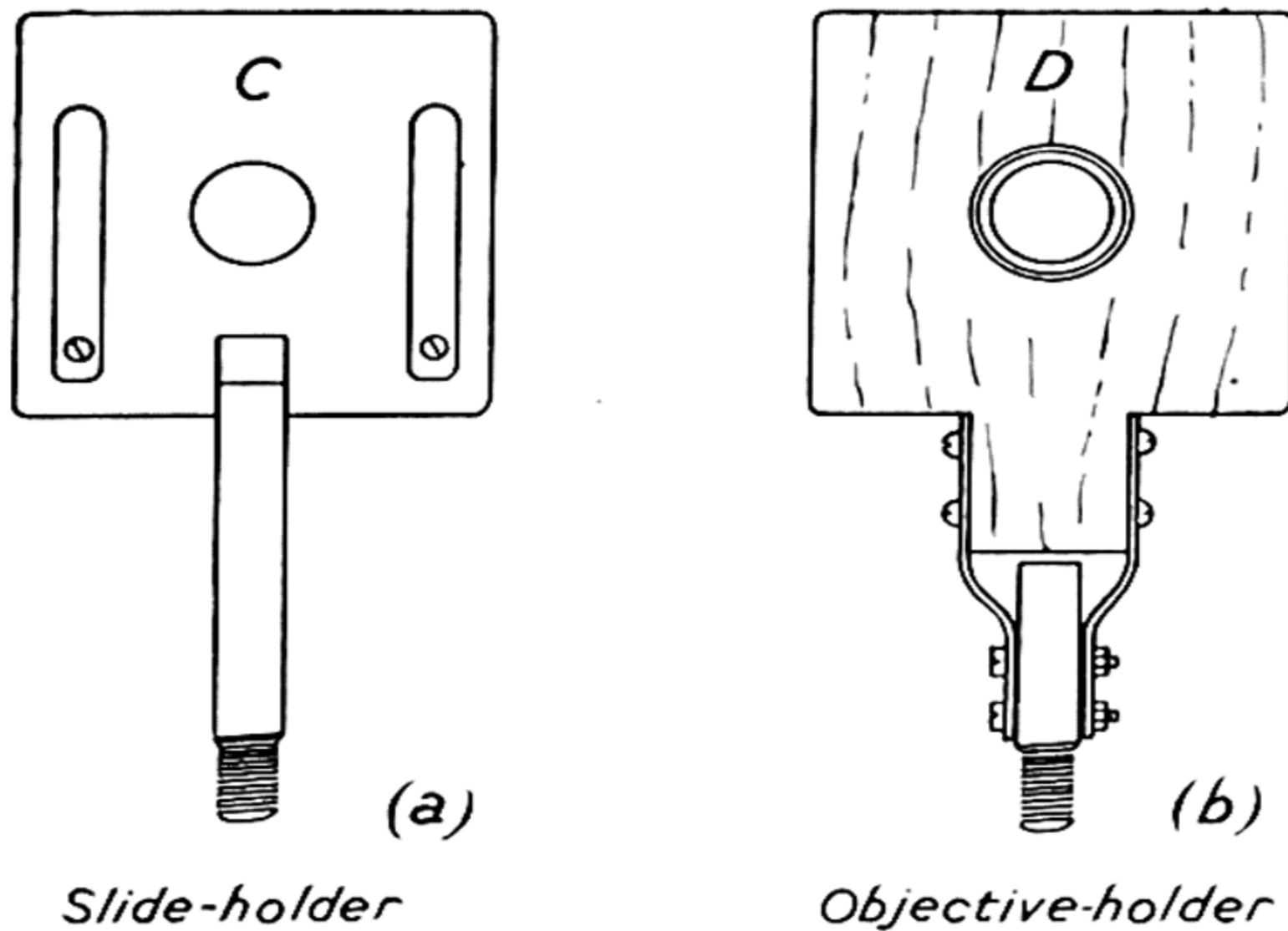


FIG. 160. PARTS FOR MODEL MICRO-PROJECTOR

illustrated. The method of supporting the lamp house and condenser is illustrated in Fig. 159 (a). *B, B* are pieces of brass soldered or riveted to the base of the lamp house and fixed with nuts and bolts to the short piece of $\frac{1}{4}$ -in. square brass rod. Slots are cut in both pieces of brass *B, B* for the lower nut and bolt, so that *A* may be tilted slightly backward and forward. The square brass rod is screwed for about 2 in. of its length at the lower end, so that *A* may be raised or lowered, and it is clamped in position in the groove of the wooden stand by means of the nut, washers, and wing-nut.

The slide-holder, *C*, consists of a piece of brass sheet about $\frac{1}{16}$ in. thick and $2\frac{1}{2}$ in. square (Fig. 160 (a)). A circular hole about $\frac{1}{2}$ in. in diameter is cut in the centre, and two pieces of clock spring, held with nuts and bolts which pass through pieces of brass tubing, each $\frac{1}{4}$ in. long, hold the slide, live box, or aquarium in position. The brass sheet, both sides of which are painted dead-black, is soldered into a hack-saw cut made in one end of a short piece of square brass rod.

D is the objective-holder. The objective is mounted in a hole cut in a piece of wood. The hole is lined with felt, glued to the wood, so that the objective is a smooth-sliding fit. The wood is mounted on the end of a length of square brass rod, so that it can be tilted slightly, as in the case of the lamp house. Both sides of the wood should be painted dead black.

It will be observed that the parts *A*, *C*, and *D* may be raised or lowered, revolved, and moved backward or forward in the groove cut in the wooden stand. This is necessary for focusing.

Suitable objectives, 1 in.–2 in. focal length, can be obtained from the following firms:

(1) Griffin and Tatlock, Ltd, Kemble Street, Kingsway, London, W.C.2. (L.40040 achromatic, 1 in. focal length. With the screen 5 ft. away this objective gives a magnification of 44 and a picture 2 ft. in diameter.)

(2) C. Baker, 244 High Holborn, London, W.C.1.

(3) M. W. Dunscombe, Ltd, 5 and 7 St Augustine's Parade, Bristol, 1.

(4) Broadhurst, Clarkson and Co., Ltd, 63 Farringdon Road, London, E.C.1.

Where there is an optical lantern available in the science room, this can be used instead of the lamp house *A* to concentrate a beam of light on to the microscope stage, if a microscope is also available, or on to the slide-holder *C* of the model micro-projector. Steps must be taken to cut off stray light from the large condenser of the lantern, and the lantern objective must be removed. Stray light can usually be cut off by placing the tube which normally holds the lantern objective close to the microscope stage or slide-holder *C*.

A very effective micro-projector can be improvised if a microscope, lamp house or optical lantern, and an old plate camera are available. There used to be a good supply of these old plate cameras. I have three, which I obtained in local salerooms for 1s. each. The source of light and the microscope are mounted as already described (Fig. 156); the lens is removed from the camera, and the tube which holds this lens is slipped over the microscope eyepiece. The image can be focused on the ground-glass plate of the camera by adjusting the bellows.

A simple micro-projector is described in Exercise 117, *Everyday Science Topics*, Book II.

Taking Photographs with the Microscope

One of the most interesting phases of working with the microscope is the making of snapshots of the world it opens up. Photomicro-

graphy it is called. The average person seems to think that the photography of microscopic objects is a complicated business involving considerable skill and the use of elaborate and costly apparatus. Those science teachers who have a working knowledge of photography, and know how to use a microscope, can produce good photomicrographs with simple apparatus and at very little expense.

The primary purpose of photomicrography is to preserve indefinitely, for anyone to see, the marvellous and varied specimens which can be studied under the microscope. With surprisingly little experience, the amateur can make photomicrographs that will bring gasps of astonishment at the beauty and strangeness of the things they reveal. Perhaps he sees something entirely new, or something particularly useful, from a teachers' point of view, under the lens of the microscope. He cannot run out and call all his pupils in to see what he has found, but he can call in his camera and later show his photographs to all the pupils, if he wishes. If he could not photograph it, it would be something like the fish that got away.

Anything that can be examined through the microscope can be photographed through it. Any specimens, alive or dead, opaque or translucent, can be used. Low-power photomicrography of fixed specimens presents the least difficulty, and is certainly well within the reach of the ordinary amateur worker.

Improvised Photomicrographic Apparatus

An efficient photomicrographic apparatus can quite easily be improvised. All that is necessary is a camera, a compound microscope, and some kind of supporting stand. Any make or model of camera can be adapted to this work. A suitable wooden stand is illustrated. The entire stand should be painted dull black.

The camera is fixed to the stand by a block of wood, which may usually be fixed to the camera with a camera screw, fitting in the threaded hole, of standard diameter, provided for a tripod screw. The camera illustrated is a quarter-plate camera. The lens of the camera is removed. Most microscopes can be used in a horizontal position, as shown, but with some makes it may be necessary to place a wooden wedge under the base to bring the microscope tube into a horizontal position. The light source *A* is the same as that already described and illustrated in Fig. 156. The special projection lamp is used here.

The microscope is placed with the eyepiece just inside the hole usually occupied by the camera lens, and this point is made light-tight with a black velvet collar, held in position, at one end on the

camera flange, and at the other end on the microscope tube, with elastic bands at each end. The mirror of the microscope is turned aside or removed altogether.

The object to be photographed is placed in position on the microscope stage and focused with the eye to the eyepiece. Micro-

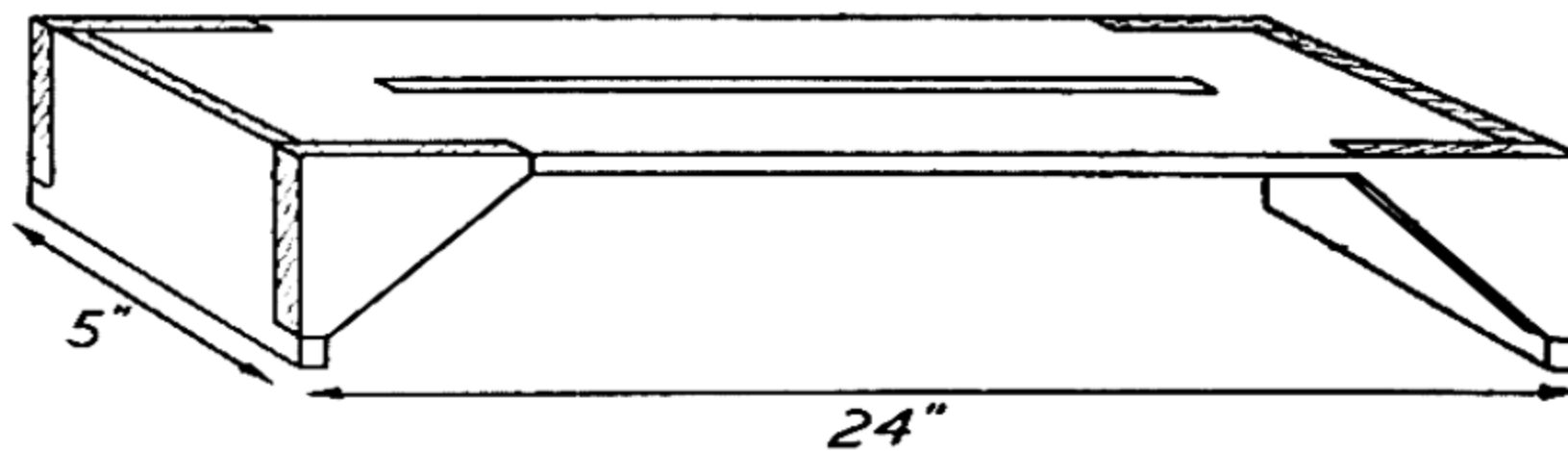


FIG. 161. STAND FOR PHOTOMICROGRAPHY

scope tube and camera are then connected. Having arranged the light to fall on the object, the image is projected on to the focusing screen of the camera. Plate-type cameras, of the kind illustrated, have a ground-glass back for focusing. With a film camera it will be necessary to remove the back, when it is not loaded, and place in the plane usually occupied by the film a piece of ground glass. The

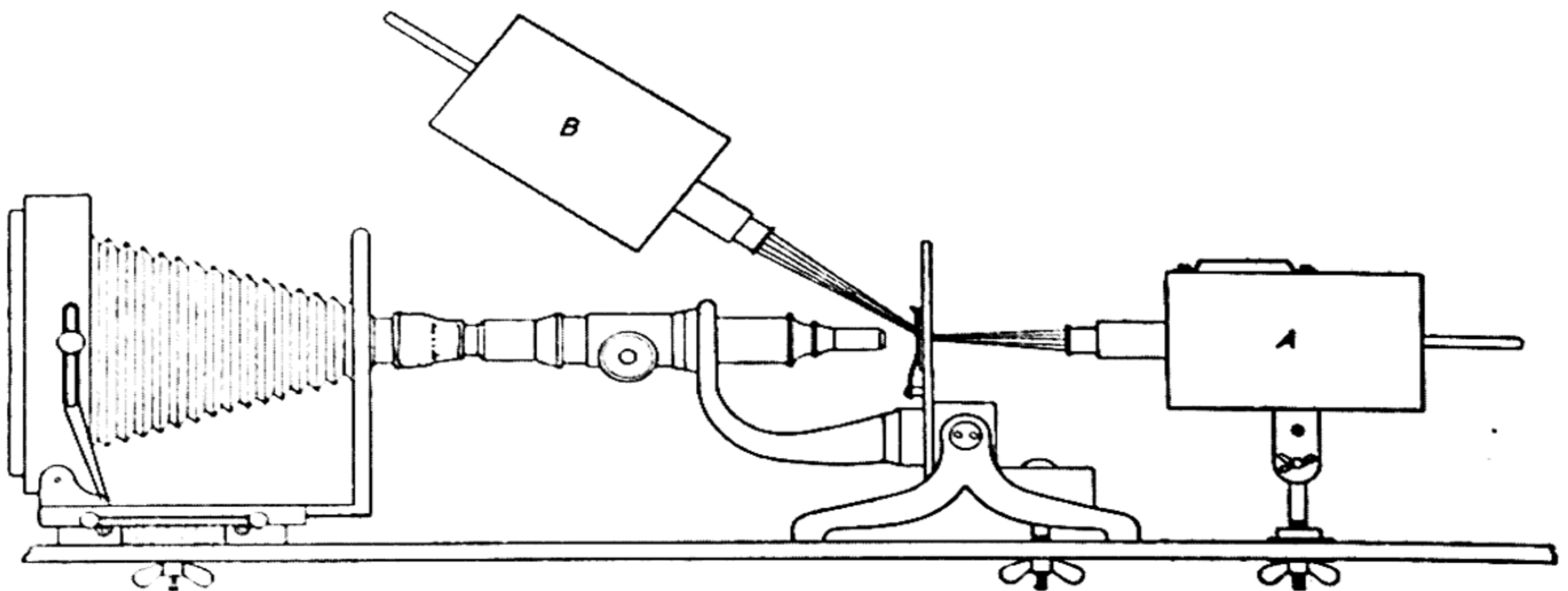


FIG. 162. PHOTOMICROGRAPHIC APPARATUS

image of the picture to be taken may be focused on this ground glass. If the image is not large enough to fill the screen, the bellows can be extended. Preferably all this work should be done in a dark room.

Low-power photomicrography is comparatively easy; the process becomes more difficult in operation with the use of increasing powers. The shortest length of the microscope tube, which gives the lowest magnification, should be used together with 2-in., 1-in., $\frac{1}{2}$ -in., or $\frac{1}{4}$ -in. objective. For a first picture select a microscope slide.

Avoid living material or anything which lacks clear, sharp outlines and distinctness of colour contrast. A fly's wing is an excellent specimen with which to start. If a fly's wing, permanently mounted, is not available, kill a fly, pull off one of its wings, place this in the centre of a clean glass slide, and put a small drop of glycerine on it. Over this place another clean glass slide, and fix the two slides together with rubber bands.

Final adjustments being made with the rack and pinion of the microscope, all parts are moved carefully and slowly to obtain a perfect circle of light on the focusing screen. When this is done the camera, microscope, and lamp house should be securely fixed with the wing-nuts. There must not be the slightest vibration of the apparatus during exposure, and this can be avoided by clamping the stand to the bench or table and keeping quite still at the critical moment.

When all is in readiness the projection lamp in the lamp house should be switched off, and, using a photographic 'safe light,' load the camera with plate or film, taking care not to disturb position of camera or microscope.

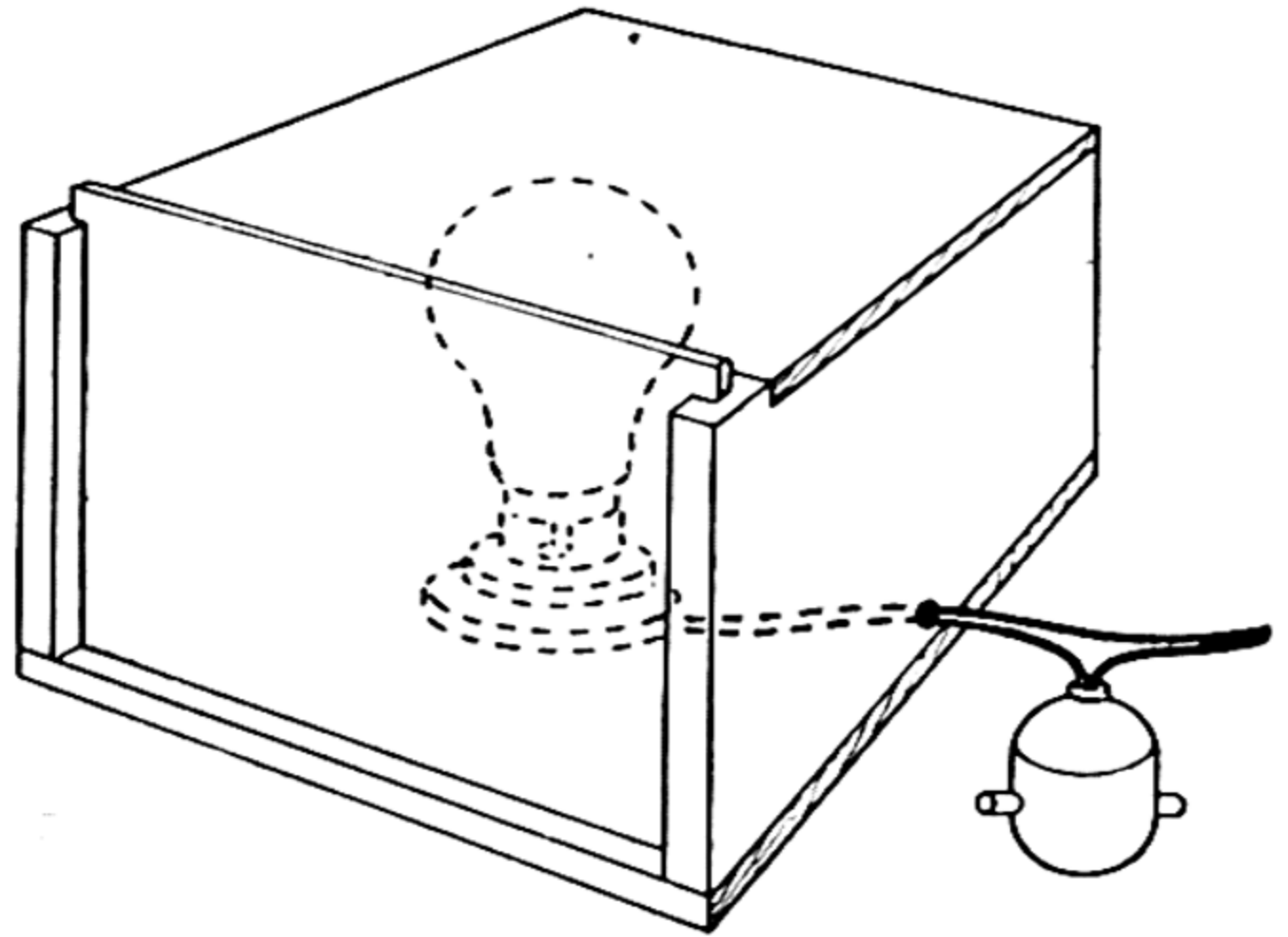


FIG. 163. PHOTOGRAPHIC 'SAFE LIGHT'

Photographic 'Safe Light'

A 60-watt electric lamp in a wooden box, with a wide opening in front in which is held a sheet of coloured glass, makes a suitable 'safe light.'

The colour to be used on the glass depends on the type of plate to be used. Dyes for colouring the glass can be made up as follows:

- (1) For highly sensitive ordinary plates. Solution for one square foot: gelatine, $\frac{1}{2}$ oz.; water, $5\frac{1}{2}$ oz.; tartrazine, 16 gr.; rose bengal, 8 gr.

Bind two glasses face to face.

- (2) For orthochromatic plate. Solution for one square foot. To the last-mentioned add a glass prepared as follows: gelatine, $\frac{1}{2}$ oz.; water, $5\frac{1}{2}$ oz.; methyl violet, 7 gr.

- (3) For panchromatic plates. Solution for one square foot. Coat two glasses with: naphthol green, 30 gr.; filter blue (hoechst 1 per cent. solution), 115 minims; gelatine (8 per cent. solution) to $5\frac{1}{2}$ oz.
Bind the glasses face to face.

In each case soak the gelatine in cold water until swollen, then melt and stir in the dye. When putting the dye on to the glass have the glass exactly levelled, and take care to get an even coating.

To make the exposure switch on the projector lamp, and, when completed, switch the lamp off. The length of the exposure is entirely a matter of trial and error. The time to be allowed depends on: (a) type of camera; (b) brilliance of the illumination; (c) type of microscope, and particularly magnification employed; and (d) subject to be photographed, with regard to its density and colour.

The best way is to try about half a dozen plates, allowing exposure times of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ minutes respectively, with the special projection lamp in the lamp house, and see which gives the best results. I have found Ilford special rapid plates most useful, and these can be developed with the first dye on the glass of the 'safe light.' Using the quarter-plate camera, the lamp house with special projector lamp, a Baker "Nature" microscope, magnification 40, and a fairly transparent slide, with colour filter, an exposure time of $\frac{1}{2}$ — $\frac{3}{4}$ minute gives good results. A trial period with length of exposures will be absolutely necessary, during which some pictures may be spoiled, and thereafter, as in any form of photography, perfection will come through the experience gained in practice.

Opaque objects may be photographed by reflected light, using the lamp house in position B, held in a retort stand. Opaque objects almost always require extremely long exposures, perhaps 30–60 minutes.

Photographing living specimens is the most difficult job. To make photomicrographs of the specimens we include under the term pond life, a powerful light source and a quick exposure are essential. Gelatine is excellent for slowing up the movements of the larger organisms; it makes the medium in which they are swimming too thick for them to go very fast. Pond life will live in it for an hour or more, and it is excellent for visual study as well as photomicrography.

To make this jelly soak a quarter of a teaspoonful of ordinary gelatine in two teaspoonfuls of cold water for ten minutes. Pour over this a cup of boiling water, and stir until all small particles are dissolved. Allow to cool and pour into a bottle. If tightly corked, it will keep for a considerable time.

Using the simple micro-projector illustrated in Exercise 117, *Everyday Science Topics*, Book II, a photographic record of slides can be obtained by projecting the image on to gaslight paper in place of the screen. An exposure of about 2–4 minutes is sufficient, but, of course, the light and shade are reversed in the resulting prints. If a piece of red colour-filter is held between the objective and the gaslight paper the image can be focused directly on to the gaslight paper, and the exposure made by removing the colour filter.

CHAPTER VII

THE SCIENCE ROOM LIBRARY

IN the words of the Board of Education Pamphlet No. 89, *Science in Senior Schools*:

It is most desirable that there should be available in the science room a varied collection of books, freely lent to the children both during the holidays and in term time, from which they may satisfy their natural curiosity, and by which that curiosity may be stimulated and guided.

Pupils should be encouraged to find the answers to questions which arise by searching the indexes of books on the science library shelves, which should hold two or three hundred books. The day of the science reader is over, and the old practice of buying a large number of copies of one such reader cannot be too strongly condemned.

The following lists are by no means exhaustive. The books are arranged in two lists, one for the pupils' and teachers' library, the other for the teachers' reference library. In each list the books are arranged in alphabetical order of authors' names. No prices have been given, as these change so frequently, and it is impossible to guarantee that all are still in print. All the books included here have been found helpful.

Teachers' Reference Books

BARNARD, J. E., AND WELCH, F. V.: *Practical Photomicrography* (Edward Arnold).

BOLTZ, C. L.: *Electricity* ("Torch" series) (Harrap).

BRAGG, SIR WILLIAM: *Concerning the Nature of Things* (Bell).

BRAGG, SIR WILLIAM: *Science in Schools* (Bell).

(An address given at a Conference of the Essex Extra-Metropolitan Association of the National Union of Teachers on October 15, 1937.)

BROOK, C. B.: *Electricity in the Home* (published by the author, Lindley, Huddersfield).

BROWN, J.: *Teaching of Science in Schools* (University of London Press).
Correlation of Mathematics and Science (Science Masters' Association) (Murray).

CROSS, M. I., AND COLE, M. J.: *Modern Microscopy* (Ballière, Tindall, and Cox).

CROWTHER, J. G.: *Science and Life* (Gollancz).

DALE, E.: *Audio-visual Methods in Teaching* (Harrap).

DANCE, H. R., AND I. W.: *An Introduction to Film-strips* (Harrap).

DAVIES, S. J., AND KENNEDY, S. J.: *Electrical Experiments for Schools and Colleges* (A. Gallenkamp and Co., Ltd, 10 Clifton Street, Finsbury Square, London, E.C.4).

- DETMER, W.: *Practical Plant Physiology*, translated by S. A. MOOR (Sonnenschein).
- DUCKWORTH, E. H., AND HARRIES, R.: *The Laboratory Workshop* (Bell).
- EDSER, E.: *Heat for Advanced Students* (Macmillan).
- ELDRIDGE, A. A., AND BRISCOE, H. V. A.: *First Aid in the Laboratory and Workshop* (Edward Arnold).
- Electrical Handbook for Women*, edited by C. HASLETT (English Universities Press).
- FARADAY, M.: *Experimental Researches in Electricity* (Dent).
- Gas Manufacture, Distribution and Use. Notes for Teachers* (British Gas Council).
- HARDY, T.: *Physics in the Food Industry* (Institute of Physics).
- Health Education Year Book* (Central Council for Health Education).
- HEATH, C. E.: *Microscope Slide-making* (Percival Marshall).
- HEYS, H. L.: *Chemistry Experiments at Home for Boys and Girls* (Harrap).
- HIND, H. L., AND RANGLES, W. B.: *Handbook of Photomicrography* (Routledge).
- Historical Apparatus* ("Modern Science Memoirs," No. 8) (Murray).
- INGOLLS, A.: *Amateur Telescope-making* (Munn).
- KERR, J.: *Newsholme's "School Hygiene"* (Allen and Unwin).
- LAUWERYS, J. A.: *The Film in the School* (Christophers).
- LEE, J. A.: *The Grid* (Murray).
- London County Council Memoranda on Curriculum I: Science in Senior Schools* (Staples).
- MEES, T.: *The Physics of Photography* (Institute of Physics).
- MELLOR, J. W.: *Introduction to Modern Inorganic Chemistry* (Longmans).
- Memorandum on the Teaching of Science in Senior Schools* (Board of Education Pamphlet No. 89) (H.M.S.O.).
- MEREDITH, C. P.: *Visual Education and the New Teacher* (Daily Mail School Aid Publication).
- Optical Aids* (Board of Education Pamphlet, No. 115) (H.M.S.O.).
- OSTERHOUT, W. J. V.: *Experiments with Plants* (Macmillan).
- PAGE, C. E.: *Simple Electrical Experiments* (Percival Marshall).
- PHILIP, J. B.: *Experiments with Plants* (Oxford University Press).
- PICKWELL, G.: *Weather* (McGraw-Hill).
- PORTER, C.: *School Hygiene and the Laws of Health* (Longmans).
- Practical Handbook on Electricity in the Home* (C. B. Brook, 10 Burwood Road, Lindley, Huddersfield).
- RAMSHAW, G. S.: *New Scientific Achievements* (Burke).
- Regulations for the Electrical Equipment of Buildings* (Institution of Electrical Engineers, Savoy Place, London, W.C.2).
- ROLLER, E., AND PRICKS, H.: *School Experiments in Electricity* (Gallenkamp).
- SAVAGE, SIR E. G.: *The Teaching of 'Colour' in Elementary Courses of Science* (Murray).
- Science Master's Book, The*, Part I (Physics); Series II, Part I (Physics), edited by G. H. J. ADLAM (Murray).

- SUMNER, W. L.: *The Teaching of Science* (Blackwell).
 TAYLOR, F. S.: *The World of Science* (Heinemann).
Teaching of General Science (Report of the Science Masters' Association, 1936) (Murray).
 TURNER, H.: *Practical Instruction for the Senior School* (Pitman).
Visual Aid Year Book (Daily Mail School Aid Department).
 VON WYSS, C.: *The Teaching of Nature Study* (Black).
 WALL, E. J.: *Dictionary of Photography* (Iliffe).
Weather Map (Meteorological Office) (H.M.S.O.).
 WESTAWAY, T. W.: *Science Teaching* (Blackie).
 WHITE, W. B., AND WATSON, T.: *Handicraft in the Senior School* (University of London Press).

Books for Pupils and Teachers

- ADAMS, J. H.: *Electricity Book for Boys* (Harper and Brothers).
 ADCOCK, K. J.: *Leather* (Pitman).
 ALLCOTT, A.: *Coal and its Treasures* (Cassell).
 ALLCOTT, A.: *Pumps* (Cassell).
 ALLSOP, F. C.: *Practical Electric Light Fitting* (Percival Marshall).
 ANDRADE, E. N. DA C., AND HUXLEY, J.: *An Introduction to Science* (Blackwell).
 ANDRADE, E. N. DA C., AND HUXLEY, J.: *Forces at Work* ("Science for Seniors," Book III) (Blackwell).
 ANDRADE, E. N. DA C., AND HUXLEY, J.: *Things around Us* ("Science for Seniors," Book I) (Blackwell).
 ANNISS, F.: *The New Practical Physics*, Books I, II, III, IV, V, and VI (Gregg).
 AUSTIN, E. E.: *The Housefly* (British Museum).
 BASTIN, H.: *British Insects and how to know them* (Methuen).
 BEAN, H. E.: *Everyday Science*, Books I, II, and III (University of London Press).
 BECK, C.: *The Microscope. A Simple Handbook* (R. and J. Beck).
 BELL, L.: *The Telescope* (McGraw-Hill).
 BELLIS, H.: *Edison and Marconi* (Chambers).
 BERRY, A. J.: *The Atmosphere* (Cambridge University Press).
 BOKER, T. T.: *Simple Photographic Experiments* (Percival Marshall).
 BONNIER, GASTON: *Name this Flower* (Dent).
 BOOTHROYD, F.: *How and why it works* (Schofield and Sims).
 BOTTONNE, S. R.: *A Guide to Electric Lighting for Householders and Amateurs* (Percival Marshall).
 BRAGG, W. L.: *The World of Sound* (Bell).
 BRAGG, W. L.: *Electricity* (Bell).
 BRAY, F.: *Elementary Science* (Edward Arnold).
 BROAD, C. D.: *Sir Isaac Newton* (Oxford University Press).
 BULL, P. G.: *Simple Experiments in Static Electricity* (Percival Marshall).
 CAMPBELL, W. W.: *Elements of Practical Astronomy* (Macmillan).

- CARPENTER, W. B.: *The Microscope and its Revelations*, edited by DR D. CHURCHILL.
- CHAMBERLAIN, J., AND QUILTER, J. H., *Knitted Fabrics* (Pitman).
- CHAPMAN, S.: *Pioneers of Progress—Galileo* (S.P.C.K.).
- CLAREMONT, C. A.: *Spanning Space* (Pitman).
- CLAXTON, W. J.: *The Story of the Weather* (Blackie).
- COCHRANE, J. A.: *School History of Science* (Edward Arnold).
- CORBIN, T. W.: *Astronomy for Boy Scouts and Others* (Pearson).
- COWLEY, H. H.: *Modern Electrical Wiring* (Caxton Publishing Company).
- CRABTREE, J. H.: *Practical Guide to Nature Study* (Jarrolds).
- CROWTHER, J. A.: *The Life and Discoveries of Michael Faraday* (S.P.C.K.).
- CUTTING, T. A.: *Electric Fun* (Cutting and Sons, Campbell, California, U.S.A.).
- DARROW, F. L.: *Boy's Own Book of Great Inventions* (Macmillan).
- DARROW, F. L.: *Masters of Science and Invention* (Chapman and Hall).
- DAVIDGE, H. T.: *Optical Instruments* (Percival Marshall).
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INDEX

- AERATOR:** for aquaria, 199–201; from a model steam-engine, 199–201
- Air:** composition of, 47; and rusting of iron, 48–49; in lungs, action of on the blood, 60; impurities in the, 60–61; ventilation, 61; and burning, 66; absence of, from inside electric lamps, 82; not heated by heat radiation, 93; pressure, the barometer and, 135–142; pressure, measured, 138–139; pressure, devices worked by, 139. *See also* Aerator; Oxygen; Weather
- Amœba,** feeding in, 125
- Amphibia** (frogs and newts), respiration in, 56–57
- Aquaria,** 54–55; aeration of, 199–201
- Archimedean screw,** 40–41
- BALL-TAP,** model, 27–28. *See also* Water-taps
- Barographs,** 139
- Barometer, the:** and air pressure, 135–142; simple mercury, 135–136; aneroid, 139–140; as a weather-glass, 139–142
- Blood:** examination of human, 60; action of air in lungs on, 60
- Burning,** experiment to show combination with oxygen in air during, 66
- Butter and milk coolers,** 147
- CARBON DIOXIDE,** 47; in respiration of green plants, 50; in respiration of yeast plants, 52; given out through stomates of leaves, 54
- Chlorine,** purifying action of, 39–40
- Chlorophyll,** absorption of light-rays by, 123
- Ciné-projectors,** 12, 204, 205, 208–212
- Clothing,** 130–133; demonstration of properties of textiles and fabrics, 130–131; weight of, 131; dust in, 131; temperature and humidity under, 132; penetration of, by ultra-violet rays, 132
- Clouds,** formation of, 149; and lightning, 153
- Coal-gas,** filling of balloons, with, 28. *See also* Coal-gas in the home; Coal-gas supply
- Coal-gas in the home,** 102–104; gas-lighters, 102–103; gas thermostats, 103–104
- Coal-gas supply,** 117–118; pressure of, 117
- Coil-former,** 35–36
- Coil-winders,** 33–34
- Colour,** 111–113; changing the colour of walls by altering that of the incident light, 111–112; appearance of coloured materials altered by colour of the incident light, 112–113. *See also* Light; Mirrors
- Compass:** magnetic, 69–70; model magnetic, 71–72; model prismatic, 72–73; ship's, 73
- Compound microscopes,** model, 178–180
- Conductors,** parallel, carrying an electric current in the same direction, attraction of, shown by dancing spiral, 107–108
- Continuous-acting pump,** 43
- Coolers,** butter and milk, 147
- Crane magnet,** model, 35–36
- Crayfish,** respiration in, 56
- Crazy mirrors,** 174
- Current-reverser,** 106
- Curved mirrors,** 173–174
- Curved reflector,** in flash-lamp, 83
- DANCING SPIRAL—see** Conductors
- Daphnia** ('water-flea'), 127; respiration in, 59
- Davy lamp,** model, 96–97
- Dew,** formation of, 153
- Digestion:** in the frog, 127; in mammals, 127–128; in man, 128–129
- Dip-needle,** model, 76
- Distillation,** 148
- Distribution board,** 34, 35, 196, 197
- Dynamo,** model, 119–120

- EARTHWORM, dissection of, 126-127
- Electric batteries, 33, 36-38
- Electric cells, 33, 36-38; Leclanché, 36-37; battery of simple, 37-38
- Electric lamps, 110-113; experiment to show low pressure in, 109-110
- Electric motor: domestic appliance worked by, 104-108; principle of, 106
- Electricity, making and distribution of, 118-122; method of driving model dynamos, 119-120; transmission of electric power, 120; a model transformer, 120-121. *See also* Electricity in the home; Electricity in the science room; Electro-magnets; Electrolysis of water; Flash-lamp
- Electricity in the home, 33-39, 104-116; a coil-winder, 33-34; factors determining strength of an electro-magnet, 34-35; model crane magnet, 35-36; cells and batteries, 36-37; simple-cell battery, 37-38; principle of electric motor, 106; magnetic effects of electric current, 106-107; attraction between parallel conductors, 107-108; electric lighting, 108-115; low pressure in electric lamps, 109-110; model illumination meter, 110-111; changing colour of walls by varying that of the incident light, 111-112; appearance of coloured materials altered by colour of the incident light, 112-113; wiring houses for electrical equipment and how electricity is distributed in a house, 114-115
- Electricity in the science room, 194-201; distribution of, 194-199; aerating aquaria, 199-201
- Electro-magnets, factors determining strength of, 34-35; powerful mains, 75; measuring the strength of, 80-81
- Electrolysis of water, 99; projecting of, on to a screen, 100-101
- lodea ("Canadian pond-weed"), 52, 124
- Epidiascope, 204
- Episcopes, 12, 204, 205, 207-208, 213, 215; model, 217-221
- Evaporation, 145-147; latent heat of, 146-147; cooling produced by, 146
- Exhausting pump, model, 137-138
- Eye, the, construction of, 133-134. *See also* Seeing
- FEEDING, 123-130; obtaining by simple plants of raw material for starch-making, 123; osmosis, 123; passage of excess water out of the plant, 124; obtaining by complex plants of carbon dioxide for starch-making, 124; manufacture of fats and oils by a green plant, 124; use by a plant of mineral salts, 124-125; feeding in *Amœba*, 125; feeding in *Hydra*, 126; dissection of the earthworm, 126-127; collection of *Daphnia*, 127; dissection of the frog, 127; dissection of mammals, 127-128; digestion in man, 128-129
- Film projectors—*see* Ciné-projectors
- Film-strip projectors, 12, 204-205, 206-207
- Film-strips, 11, 12, 13, 33, 38, 47, 64, 69, 81, 87, 98, 102, 116, 118, 122, 130, 150, 189, 215
- Films, 11, 12, 13, 32, 38, 46-47, 63-64, 69, 81, 87, 98, 102, 104, 116, 118, 122, 129-130, 142, 150, 181, 189, 214-215
- Fire extinguishers, 65-68; principle of, 66; fire-engine pump, 66; foam and soda-acid, 66-68; break-bottle type, 68
- Fire-engine pump—*see* Continuous-acting pump
- Flash-lamps, 82-86; pumping-out of air from, 82; curved reflectors in, 83; action of the lenses in, 84
- Force pump, model, 66
- Fountain, model, 45
- Frog, dissection of, 127
- GAS LIGHTERS—*see* Coal-gas in the home
- Gas thermostats—*see* Coal-gas in the home
- Gyroscope, 169-170
- HAND-FLUSHING TANKS, model, 28-31. *See also* Water in the home
- Head-pressure gauge, 39, 45
- Heart, examination of a sheep's, 57-59; action of valves of, 59; observation of, of *Daphnia*, 59

Heat, 87-98; vacuum flask, 87-90; simple thermoscope, 90-91; thermopiles for detecting radiant, 91-92; travel of heat radiation in straight lines, 92; passing of heat radiation through air without heating it, 93-94; greater emission of heat from a dead-black surface than a polished one, 94; reflection of heat radiations by a polished surface, and absorption of them by a dead-black one, 94-95; reflection of radiant heat by parabolic reflectors, 95; reflection heater, 95; comparison of heat conductivities of brass and wood, 96; comparison of heat conductivities of metal, 96; model Davy lamp, 96; comparison of heat conductivity of mercury and water, 97

Hoar-frost, formation of, 153

Hydra, feeding in, 126

Hydraulic press, 44

Hydraulic rams, 43

Hygrometers, 150-151

ILLUMINATION METER, model, 110-111

Intermittent force pump, 43

KALEIDOSCOPES, 172-175

LANTERN-SLIDE PROJECTORS, 204

Lantern-slides, 11, 12, 64, 69, 81, 116, 182

Latent heat, of evaporation, 146-147

Lenses: in flash-lamps, 84; defects of, in microscopes, 176-178; action of, in microscopes, 180-181

Light, 161-163. *See also* Colour; Mirrors

Lighting, 152-153

Lodestone, and properties of magnets, 74

MAGNETIC COMPASS, 69-70; model, 71-72

Magnetic fields, 76-78; permanent records of, 78; projecting of, on to a screen, 78-80

Magnetism, 34-36, 69-81, 106-107; loss of, in red-hot steel, 74; temporary, residual, and permanent, 74;

difference between magnetized and unmagnetized steel, 75; model dip-needle, 76; remagnetization, 76; magnetic fields, 76-80; magnetic effects of electric current, 106-107. *See also* Compass; Electro-magnets; Magnetic compass; Magnetic fields; Magnets

Magnets: model crane, 35-36; electro, 34-35, 75; making, 70-71; suspending, 72; and lodestone, 74; measurement of the strengths of, 80-81

Mammals, dissection of, 127-128

Micro-projectors, 12, 204, 224-230; construction of, 228-230

Microscopes, 175-184; simple optical bench, 175-176; improvisation of simple, and defects of lenses, 176-178; model compound, 178-180; apparatus to show the action of lenses in, 180-181; mounting of specimens for, 182-183

Mirrors, 160-175; method of making, 161; nature of light, 161-163; demonstrations of the action of, 163-165; position of the image in plane, 165-166; the periscope, 166; increase of illumination by use of, 166-167; in shop-windows, 167-168; pulsometer, 168-169; graphoscope, 169-170; other smooth surfaces as reflectors, 170-171; non-reflecting shop-windows, 171-172; reflection from, at an angle, 172; kaleidoscopes, 172-173; curved, 173-174; crazy, 174; spherical aberration, 174-175

OPERA GLASSES, 187

Optical aids in the science room, 204-216. *See also under* Ciné-projectors; Episcopes; etc.

Optical bench, simple, 175-176

Optical lantern, 12; conversion of, into film-strip projector, 223-224

Orrery, 192-193

Osmosis, experiment to demonstrate, 123

Oxygen, preparation of, 47; and rusting, 48, 49; in plant respiration, 50-51; in respiration of water plants, 52-53; given out by water

plants in aquaria, 55; means of conveying, round body, 59; part played by, in respiration, 62; necessity for, 63; and burning, 66

PARABOLIC HEATER, 95

Parallel beam apparatus, 85

Periscope, 166

Permanent magnetism—*see* Magnetism

Photographs, issued by the Science Museum, South Kensington, 69, 81, 182

Photomicrography, 230–235; improvised photomicrographic apparatus, 231–233; photographic 'safe light,' 233–235

Plug-board, 82

Plug-tap, functions of a, 26

Postcards, picture, issued by the Science Museum, South Kensington, 69, 182

Posters, 65

Potentiometer, model, 194–195

Prismatic binoculars, 187

Prismatic compass, model, 72–73

Protococcus, 51

Pulsometer, 168–169

Pumps; principle of, 41–42; intermittent force, 43; continuous-acting, 43, 66; model force, 66; simple vacuum, 136–137; model exhausting, 137–138

RABBIT, dissection of a, 59–60

Rain-gauges, 143–145

Rainbow, 151–152

Rainfall: rain-gauges, 143–145; recording of diagram registers, 145; evaporation, 145–146. *See also* Weather

Reflection heater, 95

Reflector, curved, in flash-lamp, 83

Refraction of light, apparatus to demonstrate, 85–86

Residual magnetism—*see* Magnetism

Respiration, 47–63; air and the rusting of iron, 47–49; need of a plant for oxygen, 50; necessity of oxygen for, 50–51; examination of protococcus by microscope or micro-projector, 51; examination of spirogyra, 51–52; in yeast plants, 52; in water plants, 52–53; examination of leaf

stomates, 53–54; air-spaces inside a leaf, 54; of animals—methods, 54–55; giving-out of oxygen by water plants in aquaria, 55; in water insects, dragonfly, fresh-water shrimp, and crayfish, 56; method of keeping frogs and newts, 56–57; examination of a sheep's heart, 57–58; action of the heart valves, 59; method of conveying oxygen round the body, in *Daphnia*, 59; dissection of a rabbit, 59–60; examination of human blood, 60; action of the air in the lungs upon blood, 60; impurities in the air, 60–61; ventilation, 61; the nature of sunlight, 61–62; the process of, 62–63

SCIENCE TIME CHART, 203

Scott, Captain Robert Falcon, 61

Seeing, 133–135; construction of the eye, 133; defects of vision, 134

Sheep's heart, examination of, 57–59

Ship's compass, use of, 73

Shrimp, fresh-water, respiration in, 56

Simple-cell battery, 37–38

Siphons, 29–31

Solenoids, 33, 34–35, 108

Spherical aberration, 174, 177

Spirogyra, 51, 123

Steam-engine, method of converting a model, into an aerator, 199–201

Stomates, examination of a leaf's, 53–54

Sunlight, nature of, 61–62

Sunshine recorder, 159

TELESCOPES, 184–193; astronomical, 185–186; reflecting, 186–187; terrestrial and Galilean, 187; construction and action of, 190–192; world's largest, 192–193

Temperature, fall of, with increase of altitude, 149, 155. *See also* Thermometer

Temporary magnetism—*see* Magnetism

Textiles and fabrics, properties of, 130–131

Thermometer, 155, 156–157

Thermopile, 91–92

Thermoscope, 90–91

Thunder-shower, 154-155

Transformer, model, 120-121

ULTRA-VIOLET RAYS, amount of penetration of, through clothing, 132

VACUUM FLASK, 87-88; reason why glass is silvered in a, 88-90

Vacuum pump, simple, 136-137

Ventilation, 61

WATER—*see under* Water in the Home and Water-supply and water-power. *See also* Fire extinguishers and Weather

Water in the home, 24-33; 98-102, action of the washer in a water-tap, 25; measuring the head or height of water in the reservoir above a water-tap, 25-26; function of a plug-tap, 26; increase of pressure with depth in water, 26-27; model ball-tap, 27-28; hand-flushing tank, 28-29; siphons, 29-30; another type of hand-flushing tank, 30; water-traps, 32; maximum density of water, 98; electrolysis of water, 99; projection of electrolysis of water on to a screen, 100-101

Water-pumps, 41-42; continuous-acting, 43; intermittent force, 43

Water-supply and water-power, 39-47; Archimedean screw for raising water, 40-41; the principle of the pump, 41-42; intermittent force pump, 43; continuous-acting pump, 43; horizontal and vertical pressure in a liquid, 43; hydraulic rams and presses, 43-44; fountains, 45; principle of the head-pressure gauge, 45

Water-taps, 24-28; action of the water, 25; measurement of head or height of water in reservoir above tap, 25-26; function of a plug tap, 26; increase of pressure with depth in water, 26-27; model ball-tap, 27-28

Water-traps, 32

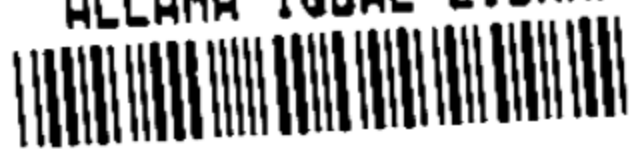
Weather, 135-160; the barometer and air pressure, 135-142; simple mercury barometer, 135-136; simple vacuum pump, 136-137; model exhausting pump, 137-138; measurement of the pressure of the air, 138-139; aneroid barometer and barograph, 139-140; barometer as a weather glass, 140-141; rain, the rainbow, lightning, the sun, and meteorological observations, 143-145; moisture in the atmosphere, the rain-gauge, 143-145; recording rainfall, 145; evaporation, 145-146; latent heat of evaporation, 146-147; cooling produced by evaporation, 147; butter and milk coolers, 147; distillation, 148; formation of clouds, dew, and hoar-frost, 149; fall of temperature with increase of altitude, 149; hygrometers, 150-151; the rainbow, 151-152; lightning, 152-153; method of making a miniature thunder-shower, 154-155; method by which earth is warmed by the sun, 155-156; thermometers, 156-157; school meteorological station, 157; wind-vane and anemometer, 158; sunshine recorder, 159

Wind-vane and anemometer, 158

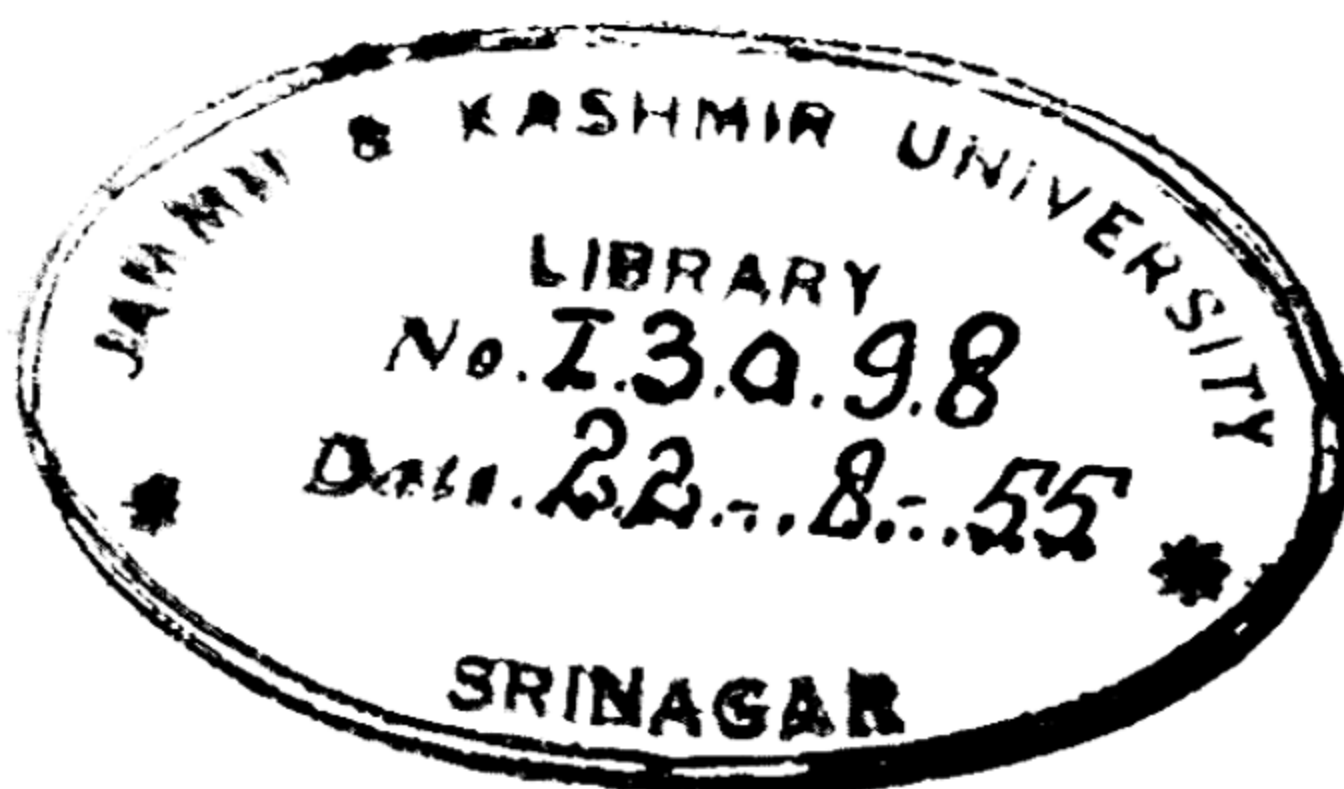
YEAST PLANT, respiration of, 52



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